LIST OF THE OFFICERS

OF

The Institution of Petroleum Technologists,

1930-1931.

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*Sir Boverton Redwood, Bart., D.Sc., F.R.S.E. (1914-1916).
Prof. Sir John Cadman, G.C.M.G., D.Sc., M.Inst.C.E., M.Inst.M.M. (1916-1917).
The Rt. Hon. Lord Greenway of Stanbridge Earls (1917-1919).
*Sir Frederick W. Black, K.C.B., B.A. (Lond.) (1919-1921).
Prof. John Samuel Strafford Brame, C.B.E., F.I.C., F.C.S. (1921-1923).
Herbert Barringer, M.Inst.C.E., M.I.Mech.E., M.I.N.A., M.Inst.Mar.Eng. (1923-1925).
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Miss CLARE DESPARD.

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THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

NOTICES.

The Institution as a body is not responsible for the statements of opinion expressed in any of its publications.

Copyright. Authors of papers and articles are requested to transfer their copyright to the Institution for a period of six months from the date of receipt of the paper. Such transfer should be made in writing when the manuscript is forwarded to the Editor.

Editors are permitted to publish abstracts, providing that acknowledgment is made to The Institution of Petroleum Technologists.

Issue of Journal. The Journal is issued in nine parts per volume, commencing in January of each year, with occasional extra numbers when necessary. The Title Page, Table of Contents and Index to each volume are published in the second issue of the succeeding volume.

Members whose subscription is not in arrear receive the Journal free of cost, and additional copies are charged at the rate of 7s. 6d. per part, unless otherwise stated. A member whose subscription is not paid by March 31st of the year for which it is due is considered to be in arrear.

Changes of Address. Members are requested to notify any change of address to the Secretary.

Papers and Articles. Members are invited to submit papers to be read at the General Meetings of the Institution, and are specially asked to forward articles for consideration for publication in the Journal. Diagrams, illustrations, etc., should be suitable for direct photographic reproduction. Authors are informed that all papers, whether for reading or for publication, will be submitted to a referee nominated by the Publication Committee.

Authors of papers published in the Journal are entitled to receive 25 free reprints of their contribution. Further copies may be obtained on payment, and orders for these should be sent to the Secretary when the manuscript is forwarded to the Editor. The free reprints do not include any discussion which may be published with the paper, but authors may have such discussion included in their reprints on payment of the additional cost.

Galley proofs of the paper to be read at a General Meeting are available at the time of the meeting, but members desirous of receiving such galley proofs in advance should apply to the Secretary.

Binding of Journals. Members desiring to have their Journals bound in cases should send them, together with a remittance of 5s. 6d. per volume, to Messrs. Speaight & Sons, Ltd., 98, Fetter Lane, London, E.C. 4. A charge of 7s. 6d. will be made for binding Vol. 10, 1924. Remittance in all cases must accompany the order.

Abstracts. Abstracts of the more important articles and patent specifications are published with each issue of the Journal, this supplement being paged independently of the transactions. Members desiring to have the Abstracts printed on one side of the paper only can be supplied with uncorrected galley proofs at a charge of 10s. per annum per copy, payable in advance.

Medals. The Redwood Medal is awarded, at the discretion of the Council, to the person who shall have made the most meritorious contribution to petroleum technology, in the form of a paper or papers published in the Journal of the Institution, during two successive sessions, preference being given to original work and to papers which have been read before the Institution and discussed. The award is not confined to members of the Institution and may be withheld if no contribution is considered to be of sufficient merit.

A medal and a prize of five guineas is awarded annually by the Council to that Student Member of the Institution who shall, in their opinion, have presented the best paper during the session.

Research Fellowship. The sum of £300 is allocated in each calendar year to a Fellowship for Research in technical and scientific problems which have a direct bearing on the Petroleum Industry. Additional grants, to a limit of £50 per annum, may also be made towards expenses.

The Fellowship is tenable for one year at an institution or in works approved by the Council, and may be renewed for a second year at the discretion of the Council.

Applicants, other than members of the Institution, must be of British nationality and must hold an Honours Degree in Science or an approved equivalent.

Applicants for the Fellowship must be in the hands of the Secretary of the Institution not later than June 1st of each year, and the necessary form, together with full particulars, can be obtained from him at Aldine House, Bedford Street, London, W.C. 2.

Advertisements. Advertisements are inserted in the Journal, and information as to terms, etc., can be obtained from Mr. Thomas Tofts, 301-302, Bank Chambers, 329, High Holborn, W.C. 1. (Telephone No. Hol. 4776.)

LIST OF ADVERTISERS.

Members are desired when making enquiries or placing orders with advertisers to mention that they have seen their announcement in the Journal.

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Benevolent Fund. The Benevolent Fund is intended to aid necessitous persons who are or have been members of the Institution, and their dependent relatives.

The Fund is raised by voluntary annual subscriptions, donations, and bequests, and all contributions should be sent to the Secretary of the Institution at Aldine House, Bedford Street, London, W.C. 2. The Fund is administered by the Council through the Benevolent Fund Committee, and all applications in connection therewith must be made on a special form which can be obtained from the Secretary of the Institution.

Appointments Register. A register of members requiring appointments is kept at the office of the Institution for the convenience of firms requiring the services of petroleum technologists, etc., it being understood that the Institution accepts no responsibility and gives no guarantee.

Library. The Institution's Library may be consulted between the hours of 11 a.m. and 4 p.m. daily. (Saturdays, 11 a.m. to 12 noon.)

PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

It is suggested that members send information regarding their movements to the Secretary, for insertion under this heading.

Mr. A. E. ALLEN has left Palestine and is now in Egypt.
Mr. N. L. ANFILOGOFF is home from France.
Mr. T. L. BONSTOW is on his way home from Mexico.
Mr. R. A. BRUCE is home from Burma.
Capt. W. H. CADMAN has returned from Persia.
Mr. J. COATES is home from Burma.
Dr. G. DE P. COTTER is home from South Africa.
Mr. F. A. FLINN has returned from Venezuela.
Mr. O. FOSBROOKE is home from Albania.
Mr. H. L. LITTLE is now in Iraq.
Mr. C. B. MCKEEVER has left South America and is in Scotland.
Mr. A. MOORE is home from Australia.
Mr. G. E. OWLES has left Peru and is in England.
Mr. F. G. RAPPOPORT has returned from Venezuela.
Mr. J. W. REID has left for Iraq.
Dr. G. SHEPPARD is home on leave from Ecuador.
Mr. W. WALLACE is home from Persia.

The Secretary will be glad to receive information as to the whereabouts of the following members:—C. A. BAUDUIN, A. E. O. COOKE, E. DAWIDSON, A. F. H. GEE, T. S. HARRINGTON, W. J. HARRIS, L. B. HOLLOWAY, A. W. IBBETT, H. F. MOON, A. F. C. PARKER, NAND LAL PASI, W. E. SHEPERD, D. S. TREBLE, R. K. VAN SICKLE and F. E. G. WATSON.

SIR FREDERICK W. BLACK,
K.C.B., B.A. (Lond.), M.Inst.P.T.

OBITUARY.

Sir FREDERICK W. BLACK, K.C.B., B.A. (Lond.).

In the death of Sir Frederick William Black, which occurred on June 7th at his home, Pinewood View, Frimley Green, Surrey, the oil world has lost a distinguished representative who will long be remembered, not least, for his keen and active interest in all educational work relating to the petroleum industry. He was elected Honorary Member of the Institution of Petroleum Technologists early in 1917. In 1919 he was made a full Member and a Member of Council and served as President for the two sessions 1919–1920 and 1920–1921. At the time of his death he was still a very active Member of Council and Honorary Editor of the Journal, which post he had held since early in 1929. During his long association with the Institution he always showed the keenest interest in its work and was at times Chairman of various Committees, including the Standardization Committee and the Finance Committee. His loss will be felt in a personal way by his colleagues and by the large number of friends his genial and kindly nature had gained for him among the members of the Institution and elsewhere.

Born in 1863, the son of the late Frederick William Black, of Newport, Isle of Wight, he was educated at the Newport Grammar School, and entered London University, from which he graduated with honours. Having decided upon a career in the Civil Service, he entered the Colonial Office in 1880, and three years later, after a further competitive examination, transferred to the Admiralty. He served on various stations abroad, including Malta and Ceylon, and for a time acted as additional Police Magistrate in the latter place. In 1903 he was appointed Director of Naval Stores at the Admiralty, and three years later became Director of Navy Contracts.

It was while he held this latter post that important developments in the use of fuel oil took place in the Navy, and his connection with the oil industry may be said to date from this time, as his work in this connection brought him into close contact with American and other producers of oil.

In 1908 he was made a Companion of the Bath, and in 1913 received a Knighthood in recognition of his valuable services at the Admiralty.

With the outbreak of the War, Sir Frederick Black was faced with the problem of expanding the organisation of his department to cope with the heavy demands of war-time supply of the Navy, and this task he carried out with complete success.

After spending the strenuous first year of the War at the Admiralty, Sir Frederick was lent to the newly formed Ministry of Munitions, under Mr. Lloyd George, by whom he was appointed Director-General of Munitions Supply. He continued to hold this office during the active period of gun and shell production, until early in 1917 when, at the request of the Indian Government, he was sent by the Ministry of Munitions to India, accompanied by technical assistants, in order to organise the local manufacture of munitions and other war materials in that country.

On his return to England he became a member of the Ministry of Munitions Council and his duty included supervision of the supply of munitions and other war material to the French, Belgian, Italian, Russian and other Allies.

In July, 1917, he was attached to the British War Mission to the United States and was given charge of the vitally important work of the Oil Committee whose duty was to organise the purchase and shipment of oil supplies from America for the three fighting services and the Board of Trade.

This work brought him into the closest possible touch with the leading oil interests of the United States as he was in daily contact with the American National Petroleum War Service Committee under the late Mr. A. C. Bedford. During the year that he spent in America on this work, he visited all the principal oilfields and refineries of the United States.

On Lord Northcliffe's return to England in November, 1917, Sir Frederick became acting Chairman of the British War Mission, and he remained in charge of the Mission until the arrival of Lord Reading in February, 1918, when he returned to the Admiralty.

In recognition of his services with the War Mission he was honoured by being made a K.C.B., and for his work on behalf of the Allied Nations he received the orders of Commander of the French Legion of Honour, Commander of the Belgian Order of the Crown and the Russian Order of Saint Anne (First Class).

Early in 1919 he was appointed one of the Government representatives on the board of the Anglo-Persian Oil Company, and shortly afterwards resigned from the Admiralty in order to become one of the managing directors of that company, a position he retained until 1923. During this period as a managing director, he played an important part in the development of the bunkering side of the company's business. After his retirement from the Anglo-Persian Oil Company's board he still continued to take an active interest in the oil business, remaining a director of the Steaua Romana (British) and of the Steaua Romana, Bucharest, as well as continuing

to serve on the boards of certain of the Anglo-Persian Oil Company's subsidiary enterprises.

During his later years Sir Frederick devoted much time to the educational side of the oil industry. He lectured on numerous occasions at the Sir John Cass Institute and elsewhere, and, as already mentioned, had been an active and leading member of the Institution of Petroleum Technologists. He was also for some years Chairman of the Morley Memorial College in Waterloo Road, and indeed had taken an active interest in this institution for working men and women over a period of twenty years.

Sir Frederick Black was well known for his literary interests, particularly in relation to the history of the Isle of Wight, and only a few months ago completed "A Parliamentary History of the Isle of Wight." He was also the author of "The Lady Isabella," a thirteenth century tale of Carisbrooke and the island. He has published, also, a number of papers on petroleum subjects, and he wrote the foreword to the latest edition of Sir Boverton Redwood's "Treatise on Petroleum," while his other contributions to the literature of petroleum include articles in Brassey's Naval and Shipping Annual, and a paper on the subject "Bulk Distribution of Oil: Depots and Storage," read at the Mining Congress held at Wembley in June, 1924.

Sir Frederick, in 1890, married Sarah Isabella, daughter of the late James Davisson, of Folkestone, who survives him, and he leaves also a family of one son and three daughters. To his widow and family we tender our sincerest condolences in their great bereavement.

MAJOR SIR ASTON COOPER-KEY, C.B.

Major Sir Aston Cooper-Key, C.B., late R.A., died on May 28th, 1930, at his home in Sussex Mansions, London, S.W., after a long illness, at the age of 69. The eldest son of Admiral the Right Hon. Sir Astley Cooper-Key, F.R.S., he passed into Woolwich from Wellington College, and joined the R.A. in 1880. He served against Arabi Pasha in Egypt in 1882, was Company Officer at Woolwich from 1885 to 1888, and Instructor in Fortification at Sandhurst from 1889 to 1896.

In 1897 Sir Aston was appointed to take temporary charge of the Government Testing Station for Explosives in Mines at Woolwich, and was a member of the Explosives in Coal Mines Committee. On January 1st, 1898, he was appointed Inspector of Explosives at the Home Office and was promoted to Chief Inspector early in 1908. He was thus occupying this responsible position during the whole of the War, a period which entailed very considerable anxiety and much hard work for him. Thus he was a member of several

most important committees, such as in connection with the supply of high explosives to British and Allied Governments in 1914; precautions and safeguards in explosives factories in 1915; the Standing Committee on Explosions at Government and Controlled Factories from 1916 onwards, as well as committees of investigation into particular explosions, such as that at Silvertown. He was also a member of a mission to France of experts on explosives in 1915.

This by no means exhausts the list of important committees on which he served during and after the War, the number of which is too great for individual mention.

Sir Aston also held several enquiries under the Merchant Shipping Act into explosions upon vessels.

He was the author of a primer on explosives and of a work on storage of petroelum spirit which was of considerable use to local authority officers in the administration of the Petroleum Acts, and also revised the fourth edition of the "Handbook on Petroleum" by the late Captain J. H. Thompson and the late Sir Boverton Redwood. He was elected an Honorary Member of the Institution of Petroleum Technologists in 1917.

During his service at the Home Office it fell to him to conduct official enquiries into many explosions at explosives factories and elsewhere.

Sir Aston, in his younger days, was an expert rackets and tennis player. He represented Wellington College and the Royal Military Academy, Woolwich, at rackets, and played cricket for his regiment. Later in life he took up Royal tennis, and became one of the foremost players, winning the Silver Racquet at Lord's in 1906 and again in 1911, 1912 and 1913, when he was over 50 years of age. He was largely instrumental in starting the Tennis and Rackets' Association in 1907, which has done a great deal for the games, both for amateurs and professionals. He was a member of Queen's Club for 32 years and on the Board of Directors for 20 years and Chairman for the last 11 years.

He was a most courteous, popular gentleman, who will be sadly missed by a large circle of friends.

Sir Aston was made C.B. in 1914 and Chevalier de l'Ordre de Leopold in 1921, and received a Knighthood just before his retirement from the Home Office in January, 1926.

He leaves a widow—Edith, daughter of Mr. W. H. Mare, of London and Newfoundland—and a son and daughter. T. H. C.

LOUIS BROWN.

We note with regret the death of Mr. Louis Brown, which occurred on May 2nd, 1930, at his home in Pittsburg.

Born in New York City in 1861, Mr. Louis Brown was educated in the public schools of Oswego, N.Y., and graduated from the high school there. He commenced his business career in the office of John E. White & Co., iron merchants, in New York City in 1879, and in 1881 was appointed their representative in Dresden, Germany. In 1883 he returned to New York and joined the firm of H. F. Tainter & Co., whiting and paris white manufacturers. In 1889 he went to the Pittsburgh office of the National Tube Co. as assistant manager, and two years later joined the Oil Well Supply Co. as assistant treasurer. He was treasurer of the company from 1895 to 1911, when he succeeded the late Mr. John Eaton as President and Chairman of the Board of Directors, from which position he retired on January 1st, 1929. In 1923 he was elected a Member of the Institution of Petroleum Technologists, but resigned in 1929 after his retirement from business.

Mr. Louis Brown is survived by his daughter and one brother, to whom we tender our sympathy in their bereavement.

NOMINATIONS FOR MEMBERSHIP OF THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

The following have been nominated for membership of the Institution of Petroleum Technologists and their Application Forms may be seen at the Offices of the Institution :—

As Transference to Members.—Francis Roger Spencer Henson, Niels Matheson.

As Associate Members —George Barclay, David Neill McKinlay, Kenneth Arthur Spearing, Arthur Augustus Weir.

As Transference to Associate Member.—Donald Thomas Jones.

As Student.—Willem Jan Hessels.

TWELFTH ANNUAL DINNER.

Members are notified that the Twelfth Annual Dinner of the Institution of Petroleum Technologists will be held at the Connaught Rooms, Great Queen Street, London, W.C. 2, on Friday, October 10th, 1930. Notices regarding the arrangements will be circulated in due course, and in the meantime members are requested to note the date.

"FUEL AND SCIENCE IN PRACTICE."

As and from July, 1930, the Annual Subscription to "Fuel in Science and Practice" will be increased to 25s. (individual copies 2s. 6d.), but as a special concession the subscription rate for Members of the Institution of Petroleum Technologists and of the Institute of Fuel will remain at 21s. per annum as at present.

THE PROPOSED HOUSING SCHEME.

In response to enquiries that have been made respecting this scheme—Council desires to inform the Members as to its present position.

Two years ago the Council was approached in connection with the scheme, which had for its object the housing together of the chief Societies and Institutions connected with the scientific and technical development of the mining and metallurgical industries, namely :—

The Empire Council of Mining and Metallurgical Institutions ;
The Institution of Mining and Metallurgy ;
The Institution of Mining Engineers ;
The Iron and Steel Institute ;
The Institution of Petroleum Technologists;
The Institute of Metals ; and
The Institute of Fuel,

the idea being to house these bodies under one roof in much the same manner as had already been accomplished by the Civil and by the Mechanical Engineers. Later on it was considered that the scheme would be more complete and effective by the inclusion of the Chemists, and the Councils of

The Chemical Society ;
The Society of Chemical Industry ;
The Institution of Chemical Engineers ; and
The Institution of the Rubber Industry,

were approached to collaborate. Each Council agreed to join the scheme on the understanding :—

(1) That the money asked for by public subscription was forthcoming ;

(2) That adequate accommodation was provided.

Each Council is represented on a Committee, the function of which is to prepare plans and formulate a scheme.

The original plan as contemplated by the Societies representing mining and metallurgy provided for the acquisition of a site in Victoria Street, Westminster, and the erection thereon of a suitable building of sufficient size to accommodate all the interested Societies and Institutions, estimated to cost £350,000.

The Institutions housed in the building will retain complete autonomy and the Institution of Petroleum Technologists will have accommodation equivalent to what it now occupies at a cost not exceeding the present cost of rent and hire of hall for meetings.

The scheme provides for a large meeting hall, to hold 500 people, in the main portion of the building, leaving five floors available for

occupation for the Societies participating in the scheme. A smaller meeting room, to hold 200 people, will also be available.

One complete floor throughout the whole building would be set apart for the General Library, which would be sectionalised, each section remaining, if desired, under the control of its Sectional Librarian.

A Restaurant in contemplation on the top floor will afford facilities for meetings under social conditions.

Finance.—The Institution cannot undertake financial participation in the building scheme, but, for the information of members, the following notes, based upon the Presidential address of Professor Thorpe to the Chemical Society in March last, explains the present financial position :—

The problem of raising the necessary money presents some difficulty in view of the present great depression of industry and the incidence of high taxation. We must look to the industries concerned to provide the greater proportion of what we require, and we hope that they will regard it as being to their advantage to do so, and will also look on it as a kind of thank-offering for past services and for the manner in which the Scientific and Industrial Institutions have provided them with information in the past. It is not too much to say that no industry based on science would exist to-day if there had not been the free interchange of thought and information which the societies included in this scheme have been formed to promote and foster. Nor is there any marked desire on the part of those engaged in industry to repudiate this debt ; on the contrary, there is not only a desire, but even an eagerness to do all that is possible. It is rather the air of uncertainty that pervades all things industrial at the moment that prevents many definite promises being given. Nevertheless, when the general appeal is issued it will contain a list of definite promises amounting to £130,000, including some munificent personal donations.

THE INSTITUTE OF FUEL.

ANNUAL CONFERENCE.

The two-day Conference of the Members of the Institute of Fuel will be held on October 22nd and 23rd, 1930, in the Lecture Theatre of the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, and Members of the Institution of Petroleum Technologists are invited to be present.

The provisional arrangements are as follows :—

October 22nd, 1930.—Sir David Milne-Watson, LL.D., D.L., will deliver his Presidential Address at 11 a.m. At 2.15 p.m.

Mr. J. Lubbock, M.A., A.M.I.Mech.E., will deliver a paper, and Dr. E. W. Smith, F.I.C., M.I.Chem.E., will also read a paper on "The Use of Coke Breeze for Industrial Purposes." In the evening the Annual Dinner and Dance will be held at the Connaught Rooms.

October 23rd, 1930.—The whole day will be devoted to a symposium on "Fuel Problems in the Mercantile Marine," to which the following authors will contribute: Mr. Sterry B. Freeman, C.B.E., M.Eng., Mr. D. Galloway, Dr. W. M. W. Meijer, Mr. W. J. Muller and Mr. W. L. Roxburgh. After the presentation of the papers, a general report upon them will be given by Engineer Vice-Admiral Sir Robert B. Dixon, K.C.B., D.Eng., and Major W. Gregson, B.Sc. (Eng.).

THE SIR JOHN CASS TECHNICAL INSTITUTE.

The Report of the Department of Petroleum Technology for the Session 1929–1930 shows that the number of class entries was 160 and the student hours 2876, the latter figure being an increase of 33 per cent. over the previous session. The outstanding feature of the work of the session was the reorganisation of the Lectures on the General Technology of Petroleum, which was grouped into one course of 24 lectures of 1½ hours each instead of two courses of 20 lectures of one hour each. This new arrangement was very successful. The course on Properties, Applications and Examination of Petroleum was again well attended and the number of entries necessitated dividing the class into two laboratory periods as in the two previous years.

PANEL OF EXPERT TRANSLATORS.

Those who require the services of a translator often experience difficulty in finding one who has both a knowledge of the language and also of the subject concerned. Proficiency in the language is not enough; the translator must also have a close acquaintance with the subject he has to translate.

With the object of overcoming this difficulty, the Council of the Association of Special Libraries and Information Bureaux have appointed a Committee to prepare a scheme for establishing a Panel of Translators having both linguistic and technical qualifications. Names of approved qualified persons are now being registered, and those who are interested, in either capacity, are invited to write for particulars to the Secretary of the Association, 26, Bedford Square, London, W.C. 1.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

THE ONE HUNDRED AND TWENTY-SEVENTH GENERAL MEETING of the Institution of Petroleum Technologists was held at the Royal Society of Arts, John Street, Adelphi, W.C., on Tuesday, April 8th, 1930, Dr. A. E. Dunstan, President, occupying the Chair.

The Secretary announced that the members elected and the persons nominated for election since the last General Meeting were :—

The following have been elected :—

As Transference to Members.—Douglas Leonard Alexander, Eric James Dunstan.

As Associate Members.—William Duff, Edward Vernon Wharton.

As Transference to Associate Member.—Hendrick Willem Slotboom.

As Students.—Jack William Clack, Samuel Elliman, Kenneth Byrne Lanyon.

At the Council Meeting, held on March 20th, 1930, the following were nominated :—

As Members.—David Allan, Henry M. de Cizancourt, Robert Crichton, Paul D. Foote, Leon Iacovitz, Richard Henry Thorburn Jobson, Alexander Reid, Alexander Walker.

As Transference to Members.—Harvey Satchell Garlick, Charles Ignatius Kelly.

As Associate Members.—John William Amner, Edgar Beardsworth Fox Auld, Vincenzo Damiani-Lugaro, Robert Hugh Dolton, Edward Leslie Gent, John Harry Maltby, Horace Edward Newton, Andre A. Perebinossoff, Hugh Charles Tett.

As Transference to Associate Member.—John Wardlow Reid.

As Students.—Walter William Scott, Thomas Speight, Joseph Edwin Walker.

As Associates.—Hugh Peregrine Henzell, Frederick Caulfield-Kerney, John Macdonald, Clarence Achilles Palmer-Chizzola, William Sigsworth, Henry David Thom.

At the Council Meeting held on April 8th, 1930, the following were nominated :—

As Members.—Robert Allan, Louis Alfred Bushe.

As Associate Members.—Almon Lee Beall, Harry Dobson, Raymond Wilson Dunster, Max Metsch, Donald Gray Phelps, Terence Charles Richards.

As Transference to Associate Members.—William Edmund Madden, Ian McCallum.

As Students.—Herbert Harland, Robert Edgar Moore.

As Associates.—William Henry Bailey, George John Hancock.

The following paper was read by the author:—

Some Features of Modern Steam Operated Deep Hole Rotary Drilling Plant.*

By Niels Matheson, M.Am.Inst.M.&M.E. (Assoc. Member).

During the last few years the depth to which wells have been carried has increased greatly. Wells over 6000 ft. are quite common, and it is reasonable to think that even 10,000 ft. holes will soon form part of the ordinary drilling programme of operating companies.

As holes have become deeper, drilling problems have become more acute, improved plant has been introduced; and the object of this paper is to describe some of the latest plant in use for drilling deep holes.

To attempt to deal with all the plant on a well would take considerably longer than the time available, and it is therefore proposed to deal only with the above surface plant.

Improvements in plant below the surface naturally affect the above surface plant. This is particularly so in the case of bits. The universal use of hard facing materials on cutting edges has considerably increased the effective drilling time, with a consequent reduction in the number of round trips, *i.e.*, pulling out and re-inserting the drill-pipe.

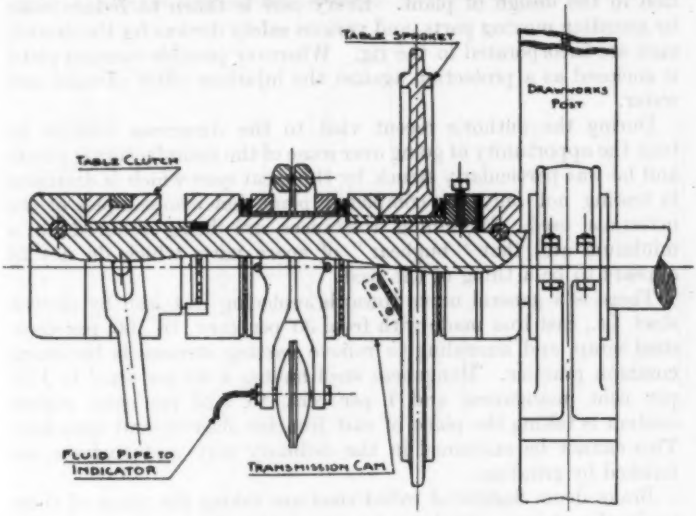
Probably the most difficult problem in drilling deep holes is that of verticality. Many holes are annually abandoned, which on survey show deviations of hundreds of feet. Cases of 500 ft. horizontal deviation in 6000 ft. drilled are fairly common.

Speedy drilling with too much weight on the bit, with the resultant wandering of the hole and increase of "twists off," due to the combined torsion and bending stresses set up, have been responsible for the introduction of the various methods of automatic torque control. These, however, form too large a subject to be included here. While weight indicators are in general use, these do not of course give any indication of the approach of the safe torque

* A précis of this paper will be found in Abstract No. 733.

limit of the drill-pipe, and there is a great need for some form of torsion indicator. This could either be fitted to the table pinion shaft or to the drawworks line shaft to record the torque in the drill-pipe. Such an instrument read in conjunction with the ordinary weight indicator would, in the author's opinion, considerably reduce the lost time due to fishing jobs and straightening crooked holes. A suggested type of fluid torsion meter is shown in Fig. 1.

The increased loads to be dealt with have given us stronger and more powerful plant, the problem of straight holes has given



DRAWWORKS TORSION METER.

FIG. 1.

us more delicate control, and the necessity of increasing the effective drilling time, *i.e.*, when the bit is actually making hole, has given us plant capable of higher speeds, particularly in the secondary operations of going in and coming out of the hole.

The most radical changes in rotary plant during the last year have been the increase in size of the rig to 136 ft. with a 26 ft. base, and the replacement of the band wheel and calf wheel by a secondary drawworks.

With the increased size of the rig there is more room for the derrick floor operations, more room at the fourble board to stack pipe and more head room for the travelling block. A breakdown

on the engine or drawworks while drilling at great depths demands a very reliable alternative hoist and the introduction of powerful secondary drawworks has considerably reduced the risk of frozen pipe.

Most of the deep wells produce either under pressure by some form of gas lift or by a pumping unit, and no plant for pumping is usually incorporated in the rig. Under these circumstances the layout of the derrick floor has changed. More room is available for racking pipe, as both sides of the plankwork can be used.

The safety of the crew has become a very important consideration in the design of plant. Every care is taken to reduce risks by guarding moving parts, and various safety devices for the derrick man are incorporated in the rig. Wherever possible running plant is enclosed as a protection against the injurious effect of sand and water.

During the author's recent visit to the American oilfields he took the opportunity of going over some of the manufacturing plants and he was particularly struck by the great care which is exercised in testing not only the completed plant but also samples of the materials used. Machining tolerances are being reduced to a minimum and that " bugbear " of spare parts which do not fit appears to be a thing of the past.

There is a general move towards replacing cast iron by electric steel, *i.e.*, cast iron made with from 30 per cent. to 100 per cent. steel scrap, and annealing to relieve casting stresses is becoming common practice. Manganese steel having a 10 per cent. to 12.5 per cent. manganese and 1 per cent. to 1·25 per cent. carbon content is taking the place of cast iron for sheaves and sprockets. This cannot be machined in the ordinary way and surfaces are finished by grinding.

Brake drum flanges of rolled steel are taking the place of those made of cast iron, which tend to crack through heating, and roller bearings are being introduced wherever possible in place of babbited bearings.

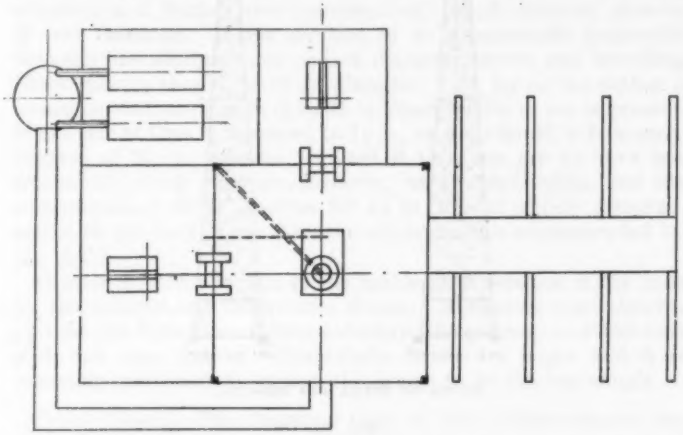
Old methods of " oil pot " lubrication have given place to oil bath and forced grease lubrication. Lubricant is now put where it is required and oil soaked plummer blocks, engine sheaves, etc., are absent from the modern rig.

In general, then, operators have now realised that their problem is not just one of making footage, but rather that they have to drill a hole to reach a definite spot below the surface with as little expense and lost time as possible. They are therefore demanding the best material to work with, and with this demand coming with increasing insistence, manufacturers are continually turning out stronger and more reliable plant, with the result

that their competitive efforts have produced some really sound and robust outfits.

While the majority of illustrations in connection with this paper show plant of American manufacture, the author is glad that he is able to illustrate and describe plant which is of English design and manufacture. Here the same care is taken in testing and the plant produced is, in many cases, quite equal to that manufactured in America.

It is, of course, more difficult for English manufacturers to keep in touch with the rapidly changing conditions in the oilfields, but from the plant the author recently inspected in England he is



LAYOUT OF DERRICK FLOOR PLANT.

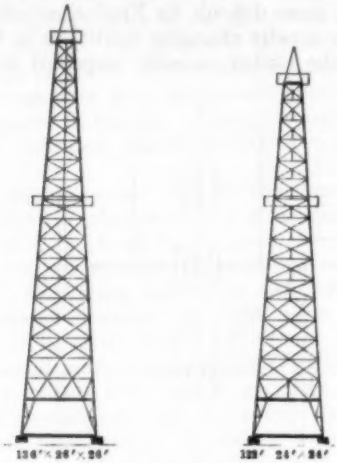
FIG. 2.

convinced that English manufacturers could prove serious competitors to American manufacturers in the Empire market.

General Layout.—The drawworks are usually set on the bull wheel side with the secondary drawworks either on the calf wheel side or more usually on the old drawworks side. The pumps are located as a rule between the two engines in the latter arrangement or next to the secondary hoist in the former case.

The close proximity of engines and pumps naturally allows of closer supervision of the steam plant and reduces the length of the steam lines. A typical layout is shown in Fig. 2.

Derrick.—The derrick is usually of galvanised steel angle construction 122 ft. high with a 24 ft. base. Many operators are, however, using the new rig 136 ft. high with a 26 ft. base and a 5 ft. 9 in. water table opening. The bottom leg angles are usually 6 in. × 6 in. × $\frac{5}{8}$ in. on the 122 ft. rig and 6 in. × 6 in. × $\frac{3}{4}$ in. on the 136 ft. rig, and the legs are reinforced with 4 in. or 4½ in. pipe running from the bottom corner plates to plates supporting the water table beams. Some form of screw adjustment is usually



TYPES OF STEEL RIG BRACING.

FIG. 3.

incorporated in order that the reinforcing pipes take their full share of the load. The derrick is set on concrete foundation piers and the derrick floor is either supported on heavy H section girders or on 8 in. × 10 in. timbers. The timber floor supports appear to be more in favour.

Extruded metal is used for the safety platform and at the fourble board and it is also sometimes laid on the derrick floor around the table to prevent slipping. A typical form of derrick bracing is shown in Fig. 3, which also shows the comparative sizes of the 136 ft. and 122 ft. rigs. The 122 ft. rig is also illustrated in Fig. 4.

Steel finger posts are becoming fairly common and in many cases these are made to swing out of the way, through the shearing of a pin, in case of entanglement with the travelling block.

Wire Lines.—1⅛ in. diameter lines are used having a safe stress of about 22,000 lbs. with a factor of safety of 5. Nine lines are usually strung giving a total safe stress of 198,000 lbs.

Loads of over 250,000 lb. have been recorded when pulling drill-pipe from extreme depths through cavings,fand it is reasonable to think that a load of 300,000 lb. may be met with under bad conditions. 1⅛ in. lines under these conditions will only have a safe stress ⅔ of that required. It is to be expected therefore that the size of lines will soon be increased to 1¼ in. diameter.

The safe stress of approximately 10 tons for the 1⅛ in. line only holds good while the line is in good condition. Unfortunately no rotary lines run under ideal conditions. The continual vibration, abrasion and flexing over comparatively small diameter sheaves is very fatiguing. If one assumes 40 as a reasonable proportion between line diameter and sheave diameter, crown and travelling block sheaves should be 45 in. diameter. As far as the author is aware no sheaves of more than 36 in. diameter are in use at present. If the size of lines is increased to 1¼ in., as it no doubt will be soon, sheaves of 50 in. will be required if the lines are to have fair treatment. Such sizes are, however, hardly practicable, and the compromise of 36 in. sheaves for 1⅛ in. lines is usually accepted, and is 60 per cent. more than the minimum size recommended by the A.P.I.

Greater attention is paid to the problems of abrasion of the lines by the sheaves and drawworks drums. Manganese steel sheaves prevent the formation of strand marks in the grooves, as is the case with cast iron sheaves. Drawworks drums are larger and it is becoming customary to groove the drums to fit the line snugly.

Crown Blocks.—The staggered type of block where sheaves are set on fairly wide centres have the advantage of quick replacement of any one sheave without interfering with the rest. Nevertheless the large angle made by the wire lines with this type of block is a distinct disadvantage (Fig. 5), and this block is fast giving way to the 5 in. line (Fig. 6) and double deck (Fig. 7) type of blocks.

The sheaves are either set on a single shaft or, as in one case, on individual shafts. Roller bearings running in hard steel races with forced grease lubrication are used (Fig. 8), and manganese steel sheaves 36 in. diameter are usual. The cat line sheave is usually of cast steel swung from one of the supporting beams.

Travelling Blocks.—These vary in size between 65 in. and 72 in., and are fitted with four (and sometimes five) manganese steel sheaves of 36in. diameter. The sheaves are mounted on roller bearings set on a 6 in. steel shaft with individual grease gun lubrication to each sheave. The side plates are either of heavy boiler

plate reinforced with steel channels or forgings or of electric steel castings. The blocks are streamlined to prevent catching at the fourble board and guards with the line slots protected by leather or canvas strips are fitted. (Figs. 9 and 10.)

In one case individual shafts for each sheave are used, and in this case the shafts are cast integral with the sheaves.

Shackles vary in design according to whether they are used with a spring hook or not. In some cases the spring is incorporated in the shackle, and in other cases two double eye-bolts connect direct to the spring hook trunnions.

Spring Hooks.—These are now nearly all built with the spring enclosed and various methods of locking the hook in any position are incorporated in the design. They are designed for various sizes of drill-pipe, so that there is sufficient movement in the spring to raise a fourble stand clear of the tool joint. Safety latches are usually fitted as standard. (Fig. 11.)

Swivels.—Swivels may be placed into two classes. Those with short washdown pipes with the mud gland at the top and those with the long pipes with the mud gland set at the bottom. (Figs. 12 and 13.)

The short pipes are usually preferred owing to the difficulty of packing the lower gland. The main thrust bearing taking the load is either of the ball, cone or bantam type. Balls have been known to crack in half and seize the swivel, but these cases have probably been due to negligence on the part of the drillers in the matter of oil. Cones are mostly used, but the introduction of the bantam bearing on the English swivel (Fig. 14) is of interest. The lower bearings taking the side thrust are usually of the Hyatt or ball type, and give little trouble. Adjustment of the main thrust bearing is made from the outside by a screwed ring acting on a thrust bearing, either cone or ball, set above the main race. All bearings run in an oil bath which necessitates a gland at the bottom. The bail, which has a limited swing, is supported from the main cast steel body below the main thrust race and the cap bolts take no load. The mud gland calls for a very reliable packing. A diagonally split hard core graphite packing seems to be most favoured.

Hose Pipes.—The two great faults with rubber hose pipes used to be that really satisfactory hose connections were difficult to make, and that the reinforcing wire tended to creep together in some places and leave the hose unprotected in others. Many ingenious connections have now overcome the first fault, and the reinforcing wire is now either embedded in the hose or covered with a wrapping of tape. (Fig. 15.)

TYPICAL 122 FT. RIG.

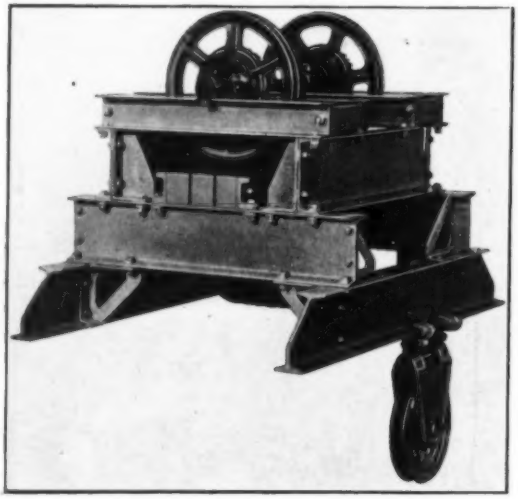
FIG. 4.

VIEW SHOWING ANGLE OF WIRE LINES.

FIG. 5.

5-IN.-LINE CROWN BLOCK.

FIG. 6.

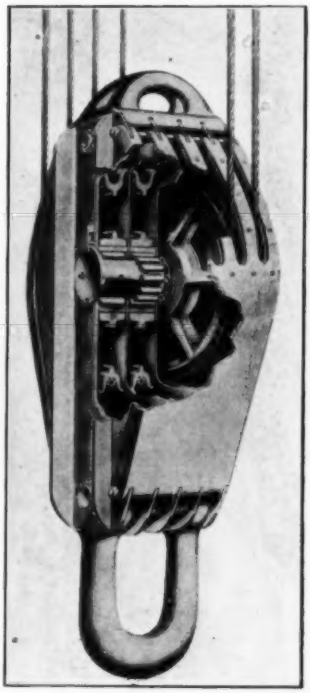


DOUBLE DECK CROWN BLOCK.

FIG. 7.

TYPE OF CROWN BLOCK SHEAVE.

FIG. 8.

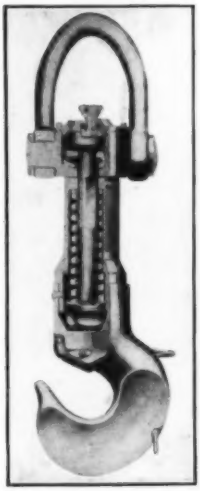


ENGLISH TRAVELLING BLOCK.

FIG. 9.

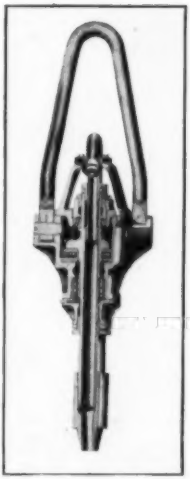
66-IN. TRAVELLING BLOCK WITH SPRING CLEVIS.

FIG. 10.



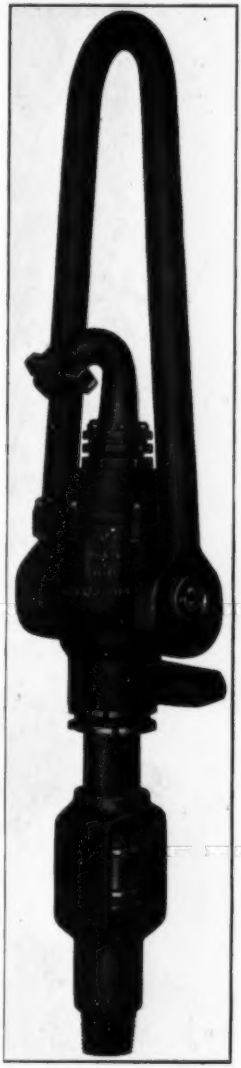
ENGLISH SPRING HOOK.

FIG. 11.



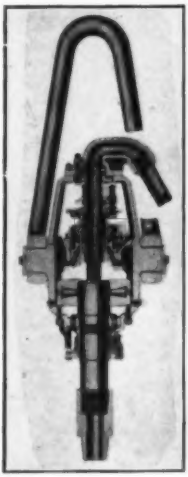
6-IN. SWIVEL WITH SHORT WASHPIPE.

FIG. 12.



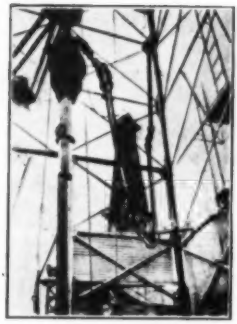
6-IN. SWIVEL WITH LONG WASHPIPE.

FIG. 13.



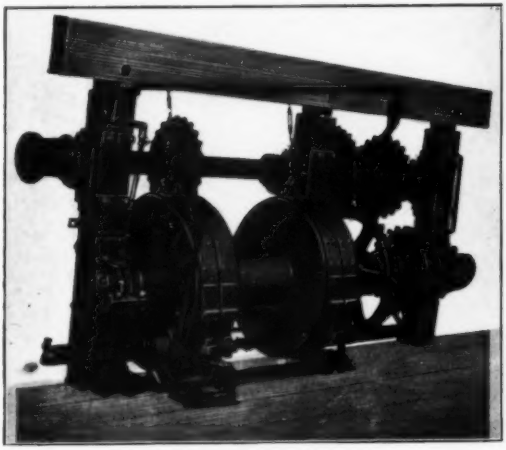
ENGLISH SWIVEL WITH BANTAM BEARINGS.

FIG. 14.



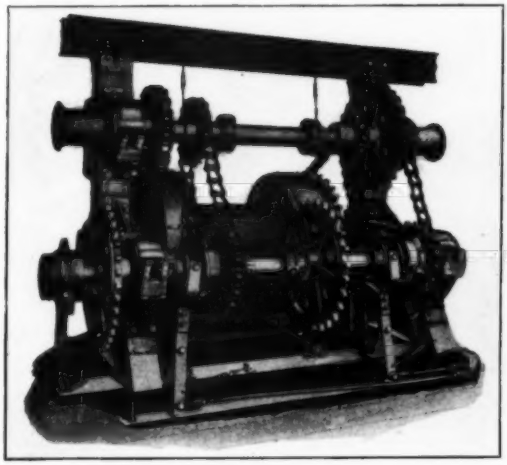
UNIVERSALLY JOINTED STEEL HOSE PIPE.

FIG. 16.



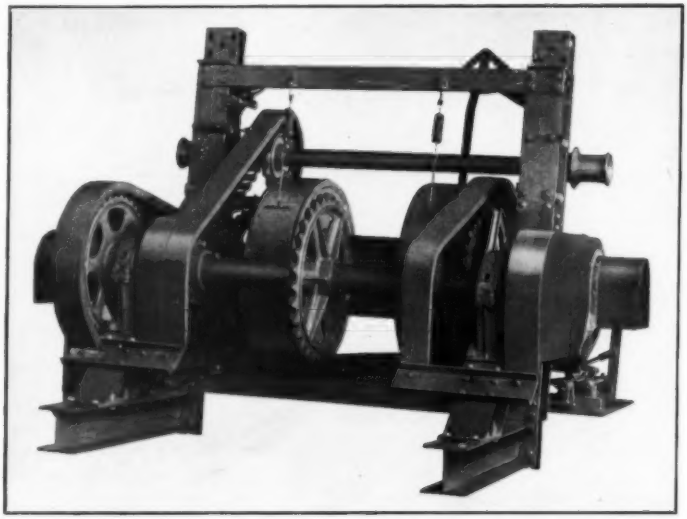
TYPE 1 DRAW WORKS.

FIG. 18.



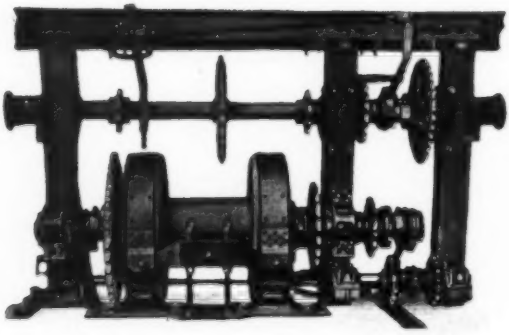
TYPE 2 DRAW WORKS.

FIG. 19.



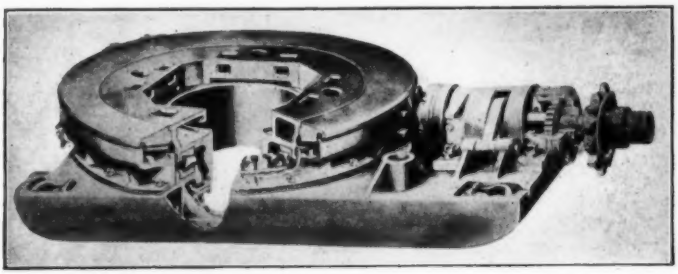
TYPE 3 DRAW WORKS.

FIG. 20.



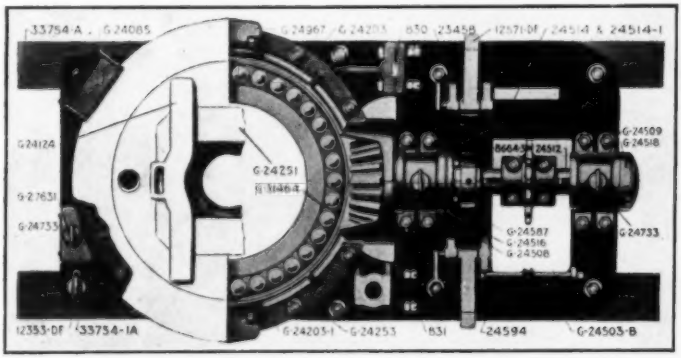
TYPE 4 DRAW WORKS.

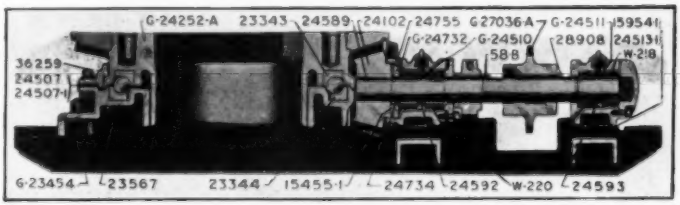
FIG. 21.



ENGLISH CONE-BEARING ROTARY TABLE WITH MACHINED TEETH.

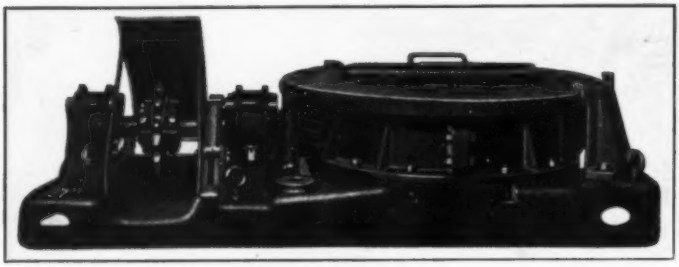
FIG. 23.





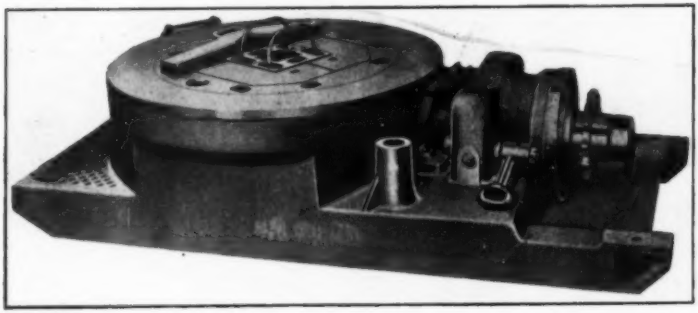
BALL-BEARING ROTARY TABLE WITH MACHINED TEETH.

FIG. 24.



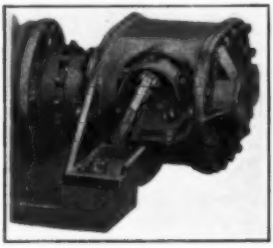
27-IN. SPIRAL DRIVE TABLE.

FIG. 25.



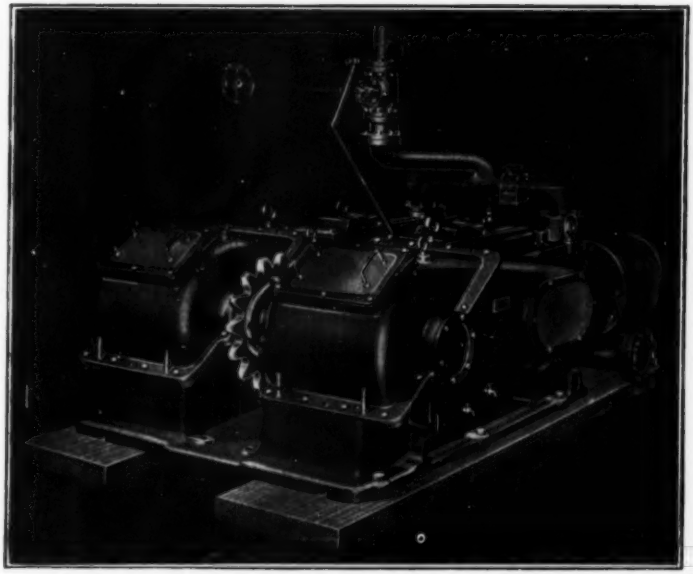
27½-IN. TOTALLY ENCLOSED ROTARY TABLE.

FIG. 26.



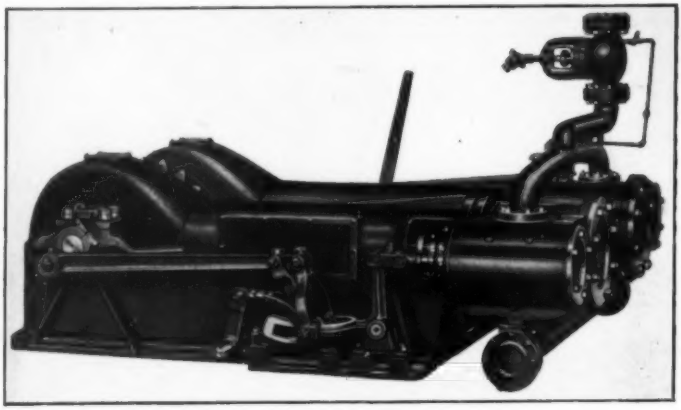
TWO-SPEED GEAR BOX FOR USE WITH ROTARY TABLE SHOWN IN FIG. 26.

FIG. 27



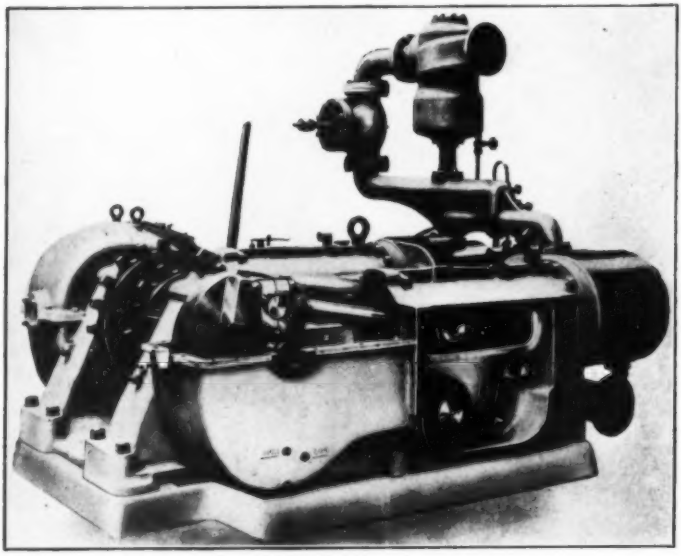
ENCLOSED "D" VALVE ROLLER-BEARING ENGINE.

FIG. 28.



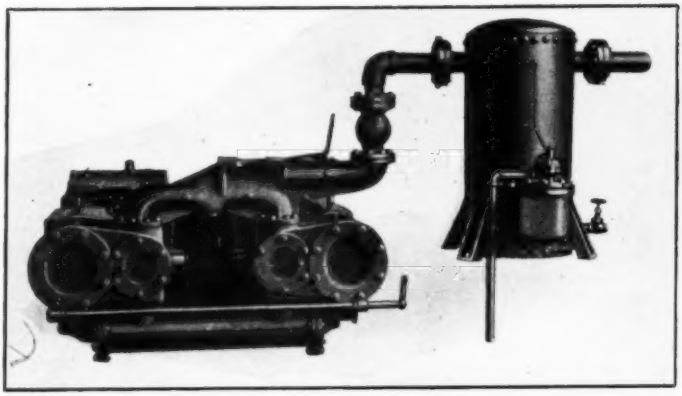
AMERICAN PISTON VALVE ENGINE WITH MONKEY MOTION.

FIG. 29.



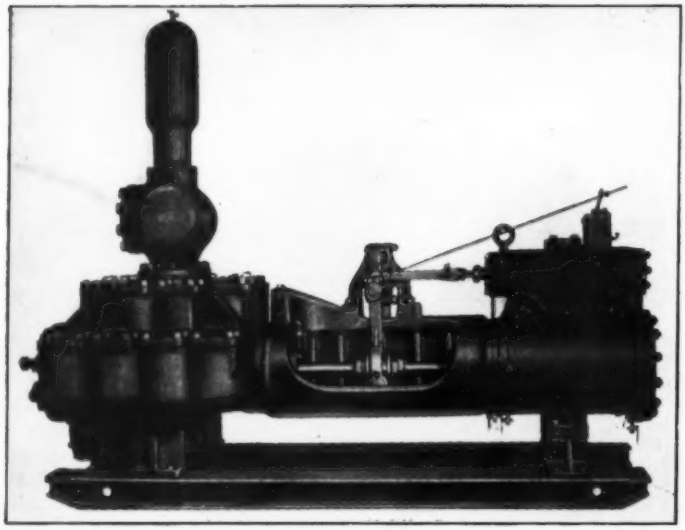
ENGLISH PISTON VALVE ENGINE WITH MONKEY MOTION.

FIG. 30.

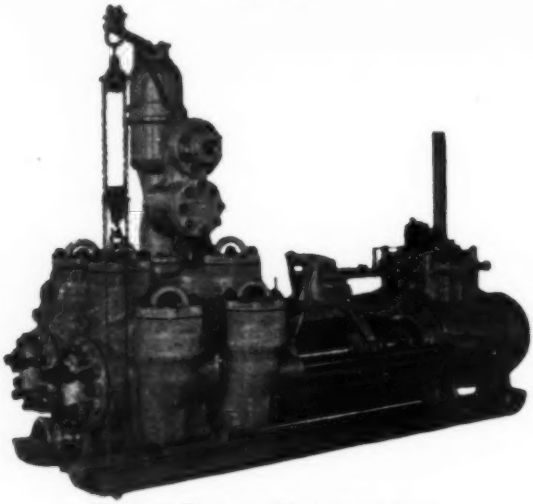


PISTON VALVE ENGINE WITH SEPARATOR AND TRAP.

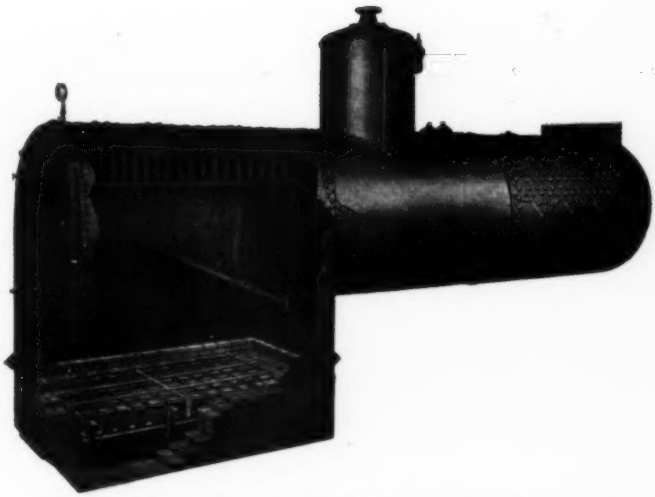
FIG. 31.



14-IN. BY 7½-IN. BY 18-IN. SLUSH PUMP.
FIG. 32.

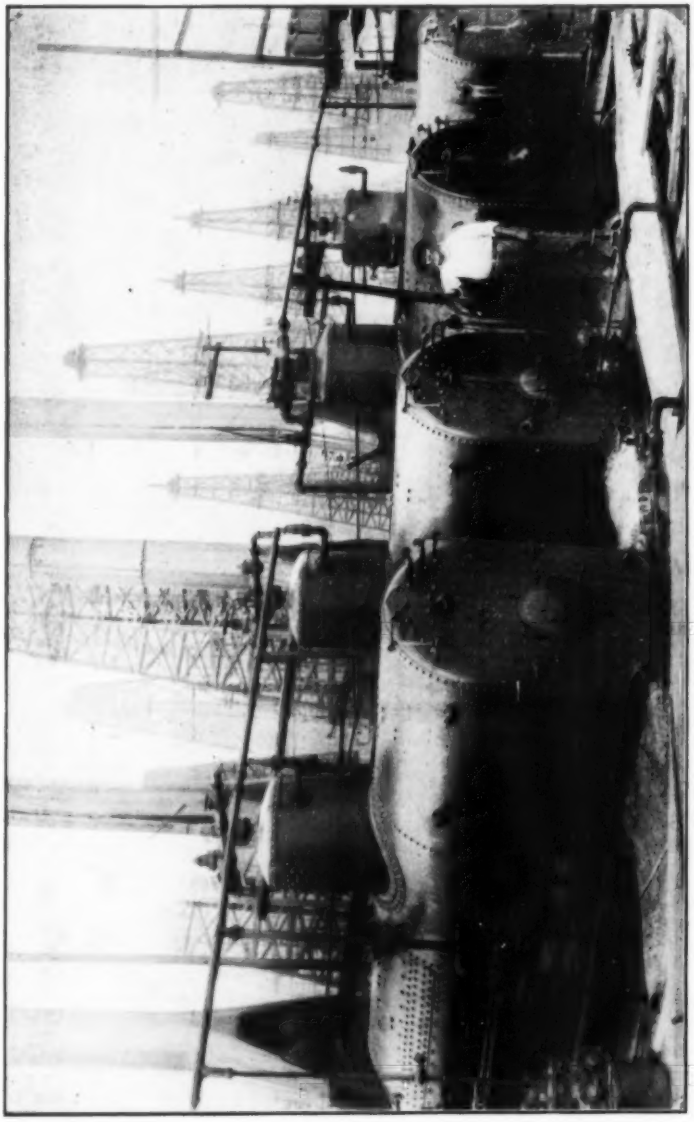


15-IN. BY 7½-IN. BY 18-IN. SLUSH PUMP.
FIG. 33.



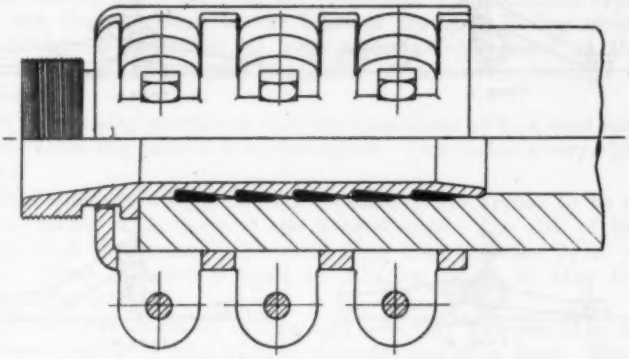
125 H.P., 350 LB. SYPHON BOILER WITH LOW PRESSURE BURNERS.

FIG. 36.



TYPICAL UNLAGGED BOILER BATTERY.
FIG. 39.

Nevertheless, with the increasing pressures now met with (possibly up to 2,000 lb. per sq. in. when re-establishing circulation), steel universally jointed hose pipes (Fig. 16) capable of easy movement and standing a pressure of 5,000 lb. are steadily being introduced. Safety chains are fitted to both types of hoses.



ROTARY HOSE CONNECTION WITH HARD RUBBER EXPANDING RINGS.

FIG. 15.

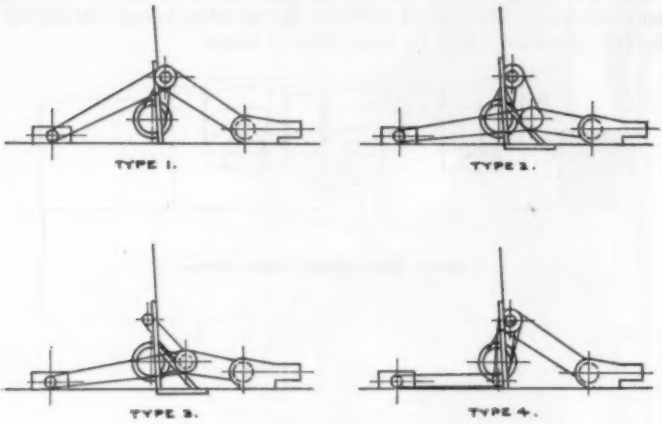
One reinforcing leg of the derrick is usually used for the standpipe, and this gives a much more rigid anchorage for the hose than an individual standpipe set in the middle of the bay. In the event of swivel seizure the leg standpipe is sufficiently strong to cause the hose to break whereas the individual pipe would probably buckle the girts and braces.

Kelly Stems.—40-ft. kelleys for the 6-in. size are mostly used, and some form of stopcock is usually set above them to deal with gas and oil blowouts.

Weight Indicators.—These are all of the fluid transmission type slung on the dead line and capable of rapid removal when the secondary drawworks are to be used. The standard gauge reading in tons is corrected for the number of lines used, and a recording gauge is usually fitted alongside. This one record showing weight, speed of pulling and inserting, time drilling and lost time gives the most useful information not only to the operator but to the designing engineer. For fishing jobs, where the standard gauge is not delicate enough to register small weights, a vernier gauge is added. This makes three revolutions to one of the standard gauge, and weights of as low as 50 lb. can be registered.

TYPICAL UNLAGGED BOILER BATTERY.
FIG. 39.

Draw works.—These can be generally classified according to the arrangement of drive as shown in Fig. 17.



TYPES OF DRAWWORKS DRIVES.

FIG. 17.

1. The standard arrangement where the drive is from the engine to the line shaft and down from this shaft to the table and drum shaft. (Fig. 18.)

2. A second arrangement has the drive from the engine to a line shaft at the back of the drum shaft. The table and cat line shaft is driven from this line shaft, and the drum shaft is driven from the cat line shaft. (Fig. 19.)

3. The horizontal drive arrangement is similar to the second type, except that the drum is driven direct from the line shaft. The cat line shaft is purely for cathead operation, and is located in front of the posts. This arrangement gives a better hang of the chain around the sprockets. (Fig. 20.)

4. The low drive arrangement is similar to the standard drive, except that the table is driven through a short countershaft set low down and giving a very low table drive, causing less obstruction on the derrick floor. (Fig. 21.)

Types 1, 2 and 3 are usually made with two posts only. Type 4 requires a third post for the table countershaft.

Two post drawworks are to be favoured, as a better alignment of shafting is obtainable with only two bearings.

Wooden posts have entirely given place to steel H section girders, and in types 2 and 3 bracing girders supporting the line shafts are fitted to short foundation joists giving a very rigid bracing to the posts.

Drum shaft and line shaft bearings are usually of the swivelling roller bearing type, and these are preferable to the babbited type. On one English design bronze bearings are used, having spring loaded grease lubricators of large capacity incorporated in the bearing base. Grease-gun lubrication of drawworks bearings is universal.

It is becoming practice to bolt the drawworks on to a steel subframe extending back to take the engine. This makes a very rigid drive.

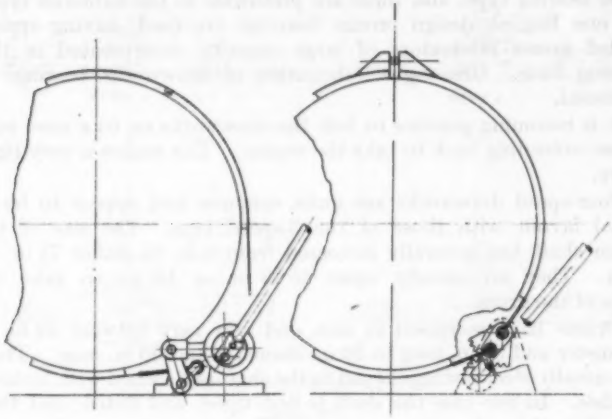
Four-speed drawworks are quite common and appear to be in equal favour with those of the 3-speed type. The size of the drum shaft has generally increased from 6 in. to either 7½ in. or 8 in. They are usually upset to 9 in. or 10 in. to take the keys of the drum.

Drums have increased in size, and now vary between 22 in. in diameter and 30 in. long to 26 in. diameter and 36 in. long. These are usually steel castings keyed to the shaft and locked with locating bushes. In one case the shaft is first upset and fluted, and then the drum is cast on in one piece. This seems very good practice except that the shaft cannot be renewed without the drum. In cases where the drum, flange and brake drums are cast integral the drum is usually split. Difficulties of dealing with expansion and cracking of the brake drums has, however, given rise to the use of separate rolled steel flanges, either riveted or bolted to the drum flanges. In one case cast steel brake flanges are used and fitted to the drum flanges in a manner which allows of free expansion and contraction. It is claimed that these cast flanges have better braking qualities than the rolled steel ones.

Water cooling is usually used for the brake flanges.

Brake bands are usually made in one piece to take 12 in. lining, either in one strip or in short lengths. The bands are usually fixed to the foundation by equalising levers, although the use of differential brake levers does not, of course, necessitate this. The increased loads to be dealt with and the consequent increase in the tendency of the brake lever to kick back has led to the introduction of some form of reduction gear to increase the mechanical advantage of the brake. This is usually done by means of a cam. (Fig. 22.) Sprockets and clutches are of cast steel or manganese steel with machined faces ground and loose sprockets are grease-gun lubricated.

Clutch controls are usually located on a bedplate running the length of the drawworks and forming a template for the brakeband bolt holes. This considerably facilitates erection. Standard catheads are fitted on the control side, and these are sometimes made with a replaceable liner to take the wear of the cat line.



TYPES OF GEARED BRAKES.

FIG. 22.

Automatic or clutch operated catheads are almost universally used for breaking out pipe. The former type usually release after one complete revolution, while the latter type can be stopped at will. The introduction of these catheads has done much to reduce the number of accidents on the rig.

All moving chains and sprockets are protected by heavy steel plates, and in some districts local regulations demand the guarding of the brake drums against bursting as well.

Many forms of line spooler are on the market, but the usual type used is with rollers slung between two weighted wire lines.

Secondary drawworks—in place of calf wheels—are usually of the two-post heavy two-speed type, and sometimes a spare sprocket for emergency table drive and a sand reel are incorporated in the design. These drawworks do not as a rule have roller bearings.

Of the two types of chain in use both have more or less equal disadvantages. The straight link type is less liable to stretch, but requires a special cranked link if the length of the chain necessitates an odd number of links. Both types are in general use.

Rotary Tables.—The size most in use is the 27-in. Make and break rotaries are not much used, as pipe is spun in from the cathead. The rotaries are built with a cast-steel base, which is usually electrically annealed. The main differences in design are the methods of supporting the table, the type and construction of the drive ring and pinion, and the location of the driving sprocket. The tables either run on cone bearings taking the down thrust with bronze side thrust bearing rings, or on ball bearings taking the combined down and side thrust. Many arguments in favour of each method can be put up. There is no doubt that cone bearings in themselves do not deal with side thrust, otherwise there would be no need for the bronze bearing rings. There are also no spacers fitted between the cones, and this causes considerable friction and consequent heating up.

The ball races (in which the races usually support from 30 to 40 per cent. of the circumference of the balls) are spaced, and deal with the combined thrusts; nevertheless, there is less actual supporting area than with cones. Lubrication of the bearing races is from a supply tank cast integral with the holding down ring, and overflow of oil from the race keeps the side thrust bearing rings lubricated.

Gearing has also been the subject of much discussion. The gear ring is either cast integral with the table or is a separate steel ring with machined teeth, shrunk on to the table. As long as gearing is not totally enclosed from sand and dirt there will always be wear. The cast teeth have as a rule a very hard surface which stands up to the heavy running for a considerable time. When this hard skin is worn through wear becomes rapid. Building up with the torch is usually possible, and if the job is to be completed by grinding it is necessary to have no lip to the teeth, as in some designs, in order that the grinding wheel may enter. The same holds good with spirally cast teeth which are difficult to grind. As, however, the table is usually ready for replacement by the time the teeth are worn out, this is not a great disadvantage.

With the machine-cut gear ring, replacement of the ring alone is of course possible, though it is quite a difficult job in the average field repair shop to get the old ring off, heat the new ring equally, and fit it snugly.

The bevel pinion is usually a machined steel forging keyed to a 4½-in. shaft, and running in two double cone or hyatt bearings capable of adjustment and lubricated by grease gun.

The table lock is fitted between the two bearings as a rule. The sprocket is of the split type if located here, and solid if fitted at the end of the shaft. In the latter case it is usual to fit a key protecting cover. On one or two tables the lock is a vertically sliding pin in the

base engaging with one of a series of holes in the table bottom. This prevents jarring on the gearing. Most tables have covers completely surrounding the gear ring with the exception of an opening for the pinion.

Bushings are of cast steel of the square top drive type, and locking bars are usually of the type having hinged hook ends.

Types of rotary tables are illustrated in Figs. 23, 24 and 25.

The author recently saw a 27½-in totally enclosed oil bath rotary of the ball-bearing type which seems to have solved the problem of sand and dirt getting into the gearing and bearings. Here there is no holding-down ring—a second ball race fitted below the main race taking the up-thrust. A ball thrust race is fitted on the pinion shaft in addition to double Hyatt roller bearings, and the locking pawl is entirely enclosed. This particular table (Fig. 26) is of interest inasmuch as provision is made for a two-speed gear box to be fitted at the end of the shaft to allow for half speed for coring, etc. (Fig. 27.)

Engines.—These are nearly all of the 12 by 12 twin cylinder oil bath type capable of developing 425 h.p. at 200 r.p.m. with 250 lb. steam pressure. Steam valves are either of the balanced piston or slide D type, and the valve motion is either of the standard link type actuated by eccentrics, or of a type of monkey motion actuated by a short crank attached to the end of the crankshaft. The stroke of the piston valve is usually shorter than that of the slide valve, and less wear therefore takes place. The piston valves will however not lift for water, and are apt to hammer badly unless the steam is dry. They give less trouble however than the heavier D-valves. Lubrication of the steam cylinders is by forced feed lubricator delivering into the steam manifold, and piston valves appear to get better lubrication than slide valves.

The standard form of valve gear is located on the inside of the cranks, and is somewhat difficult to get at. The eccentric links and sheaves are of cast steel, and working at a linear speed of something like 500 ft. per minute a certain amount of wear takes place, even though they are running in an oil bath. In one case bronze liners are fitted between the hub and sheave, and this is easily replaceable.

The various forms of monkey motion are fitted on the outside of the cranks, though the valves are on the inside of the cylinders. They are therefore much easier to get at. A roller bearing is usually used on the end of the valve crank. One design of engine of the slide valve type has a steam-operated piston which throws over the reversing link. Crankshafts are usually 5 in. or 5½ in. in diameter, and run in two large roller bearings, although in some

cases two and in others four babbited bearings are used. The babbited bearings certainly give warning of approaching trouble, whereas the roller type would probably seize up without warning in the event of a broken roller. Alignment with two roller bearings is more simple than with two or four babbited bearings, although again it is simpler to replace worn babbit bearings than to replace roller bearings.

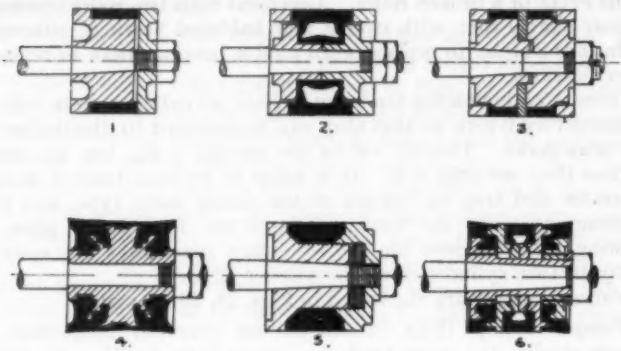
There is an increasing tendency to have all cylinder drain valves connected by levers, so that they can be operated by the driller at the drawworks. Throttle valves are usually 4 in., but on some engines they are still 3 in. It is usual to fit some form of steam separator and trap on engines of the piston valve type, and the tendency to make the former of large size from boiler plate is growing. The engines for the secondary drawworks are usually 10 by 10 twin cylinder or single cylinder 12 in.

Various engines are illustrated in Figs. 28, 29, 30 and 31.

Pumps.—Pumps (Figs. 32 and 33) are generally made with a longer stroke, the most used size being 15 in. by 7½ in. by 18in. Running at a normal speed of 40 r.p.m. with a steam pressure of 200 lb., these will deliver 350 gallons per minute against a pressure of 840 lb. with a 7½-in. liner, and 175 gallons per minute at 1,600 lb. with a 5½-in. liner. It has been said that these large pumps cause a certain amount of caving by washing down the hole, and many operators talk of going back to the 12-in. stroke pump and using three pumps instead of two. The advantage of having a piston speed of about 120 ft. per minute with only 40 r.p.m. possibly outweighs any disadvantages the large pumps may have. At this speed wear is much less due to the smaller number of reversals of the pistons and lifts of valves. The pumps are all fitted with piston valves, and with the slow speed and the pistons fitted with the port outlets at the bottom there is no trouble with water. Lubrication of the steam cylinders is by forced feed lubricator and cushion and water drain valves are usually fitted. The water end is of annealed electric-cast steel, having either 8 or 16 valves. With 16 valves these can of course be smaller and therefore lighter, but double the amount of maintenance is necessary. There are many types of water valves and water pistons, some of which are illustrated, which give good service under the conditions for which they are designed. Valve seats are usually of forged and hardened steel ground to size. Types of mud pump pistons and valves are shown in Figs. 34 and 35.

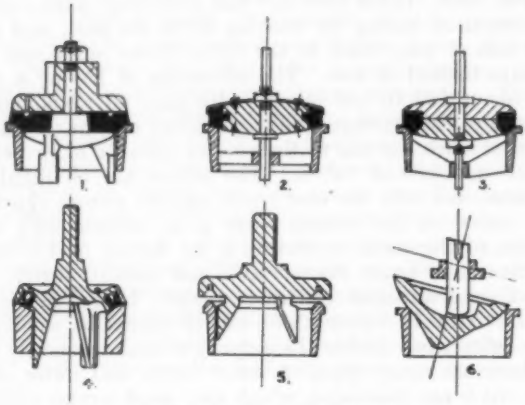
Liners are of cast iron sometimes centrifugally cast, and adjustment of the liner packing is usually possible from the outside while the pump is running. With the increased pressure some pumps are reinforced with steel tie bolts running throughout their length.

Rods are of nickel or chrome steel, with ground finish, and the water rods are usually kept clean by a running stream of water. Air bottles are being built of much larger capacity, and in one case a



TYPES OF MUD PUMP PISTONS.

FIG. 34.



TYPES OF MUD PUMP VALVES.

FIG. 35.

small chain block is fitted to the top of the bottle to facilitate the removal of the valve covers.

It is customary to set the pumps on the ground rather than on the derrick floor level to give a low suction lift, and suction pipes

are usually welded up to prevent leakage of air. Pumps are sometimes compounded to deal with high pressures, and fittings on the discharge manifold are usually of solid forgings machined out and capable of standing 3,000 lb. per sq. inch. An automatic valve is usually fitted in the discharge manifold. This is a floating piston which automatically closes either one side or the other of the main tie-piece leading to the standpipe, and it permits the pumps to be changed over without interrupting the circulation.

Boilers.—It is usual to set either three or four boilers varying between 100 and 125 h.p. with working pressures varying between 175 and 300 lb. per sq. in. The general design of the boiler has not changed other than in size. Solid steel mudrings are fairly general, and the dome location is usually over the barrel instead of over the waggon top. This prevents water being drawn off the crown sheet by sudden steam loads reducing the pressure.

The introduction of a syphon in the furnace of one make of boiler is of interest (Fig. 36.) This causes rapid circulation of the water, increases the heating surface, and in the event of low water keeps the crown sheet wet, thereby preventing possible burning.

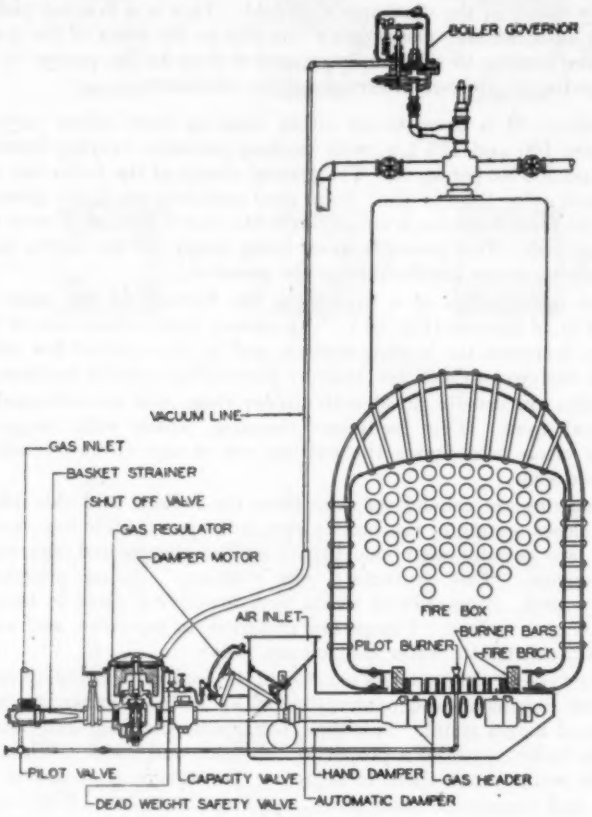
Tubes are usually fitted with copper rings, and are arranged in vertical rows. This facilitates cleaning, which with staggered tubes often necessitates the cutting out of one or two tubes to remove scale.

Waggons are usually separate from the boilers, and this allows of a closer setting of the boilers in a battery. Double 4-in. steam lines are usually used, one supplying the pumps and the other the engine. This prevents "wire drawing" during periods of heavy load. Stopcocks in steam lines are giving place to bronze-seated gate valves. Pumps are preferred to injectors, and occasionally automatic water controls are fitted.

One type of water control consists of the feed valve being operated by the expansion and contraction of an inclined expansion tube made of monel metal. This pipe, being connected top and bottom to the boiler, contains a proportion of steam and water. When the boiler water drops there is a greater percentage of steam in the pipe and expansion takes place, opening the valve. High water contracts the pipe and closes the valve.

When the ordinary pipe type of gas burner is used it is usual to build some form of sub furnace to increase the length of the furnace. A better way, however, is to burn the gas in its normal way—*i.e.*, upwards, in low-pressure multiple jet burners. These work at pressures varying between a few ounces to 10 or 15 lb. without steam injection, and give a good heating flame without noise. Gas controls are sometimes fitted. These regulate the

pressure, and therefore the quantity, of the gas going to the burners by the boiler pressure. In one form of control the amount of air is also kept in proportion to the amount of gas being consumed. (Fig. 37.)

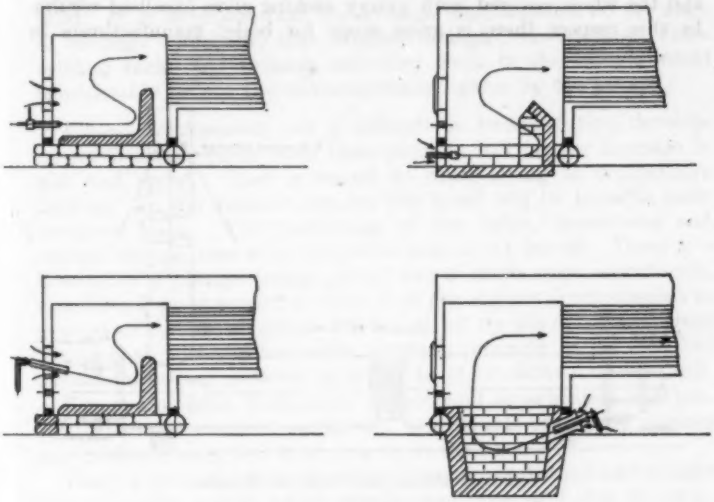


TYPE OF AUTOMATIC BOILER CONTROL.

Fig. 37.

Oil burners are mostly installed under the back end of the mud-ring in some form of shallow sub-furnace with suitable baffling. The more usual types of sub-furnaces are shown in Fig. 38.

Economy.—The author has attempted to show how manufacturers of plant have helped the operator by giving him good plant. Now for the other side of the picture. Does the operator make the best use of the plant available? The visitor to the average drilling well will no doubt be struck by the fact that very little



TYPES OF BOILER FURNACES.

FIG. 38.

effort is made to economise in fuel and material. With the large surplus of gas in some fields there is, of course, not much incentive to economise. Yet in districts where gas has to be bought and paid for as it were the economic aspect is of grave importance.

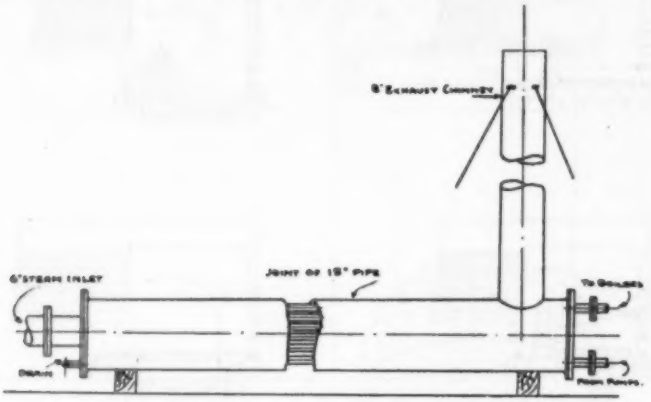
In America very few boilers are lagged, steam lines are usually bare and only a few attempts to utilise the exhaust steam for feed water heating are made. Fig. 39 shows a typical battery.

Gas and oil fuel is usually burnt in the boilers in a very primitive way, and as long as the safety valve keeps popping off the driller seems to be quite happy. Boiler doors are either left open or are missing altogether, and cold air is allowed to get into the furnace without doing much useful work in aiding combustion.

The author has seen drilling plant—and quite good plant too—almost falling to pieces through lack of attention. There seems to be no halfway condition. Plant is either "running fine and

dandy" or "all blowed up." Yet the efforts of designers seem to be of little avail if plant is allowed to run to death through faulty lubrication or lack of adjustment until too late.

Lagging of boiler and steam lines and protection of them from cold winds effect large economies in fuel. A lagging of mud and chopped rope with an embedded layer of old stranded sand line, and the whole covered with gunny sacking gives excellent results. In this respect there is great scope for boiler manufacturers in



EXHAUST STEAM FEED WATER HEATER.

Fig. 40.

marketing boilers with permanent laggings. Feed water heating, provided the water can be heated to near 180° F., gives further economy.

Feed water heaters welded up out of old 12-in. casing are easy to make and give good service (Fig. 40). Probably the greatest waste in fuel is through boilers of too small capacity being used. Fuel is then literally poured in, in an attempt to get more steam than the boilers are capable of producing.

Many operators use no gas and oil controls, yet these pay for themselves in fuel economy very rapidly.

Automatic control of the feed water not only gives good steam the whole time, but saves many a crown sheet from falling through low water, and here again the initial cost of installation is nothing compared to the ultimate saving.

It has always been a debatable point as to whether it is wise to blow boilers down frequently. Every blow down helps to deposit

scale, and boilers are usually allowed to run too long before removing this. The installation of a spare boiler in the battery to allow of regular cleaning is surely an economy.

Operators are continually grumbling at the amount of work involved in changing liners, pistons and valves on the pumps, and yet little attempt is made to remove the cuttings from the circulating mud. It is estimated that the average mud contains 50 per cent. of cuttings. Probably this estimate is high; nevertheless, extra settling tanks and suitable collecting trays in the trough would considerably reduce the consumption of spares by the pumps.

Future Developments.—It is difficult to foresee future developments in rotary plant other than possible still further increase in size and speed. That is bound to come owing to competitive drilling. In the author's opinion the trend will be towards more compact plant. The combining of the table, drawworks and engines on one base as a composite unit is not far off. There is a possibility of plunger pumps giving way to multi-stage centrifugals, and there is great scope for crude oil or gas engines direct coupled to generators for the electrical driving of all rig plant. Such plant would have to be in two units normally working in parallel, but capable of instant isolation in the event of breakdown on one unit.

For steam drive, feed water heaters and superheaters will probably become standard auxiliaries, and double expansion engines will no doubt soon find their way on to the rig.

There is no doubt that the rotary system has distinct advantages over the cable system under certain conditions, and that its introduction has been the greatest change in method since the beginning of the oil industry. Nevertheless, the author does feel that the continual improvements in rotary plant design are after all only improvements in the details of a scientifically unsound method of making hole. The transmission of torque through some mile and a half or two miles of small diameter pipe to the scene of operations is a makeshift at the best, and in his opinion there is no doubt that the future systems of drilling will have the actual motive power at the bottom of the hole.

The most convenient ways in which the power can be transmitted, other than by torque through drill-pipe or by vibration through wire line are by fluid pressure or electric cable. Many designs of turbo rotaries actuated by these two methods have been experimented with, but even with the power unit at the bottom of the drill-pipe there is still torsion in the pipe and crooked holes are not eliminated.

It would appear that a combination of a rapid percussion system and mud circulation with the power unit contained in the bit would

have none of the present disadvantages. Purely as a matter of interest, the following is suggested as a possible future drilling system. (Fig. 41.)

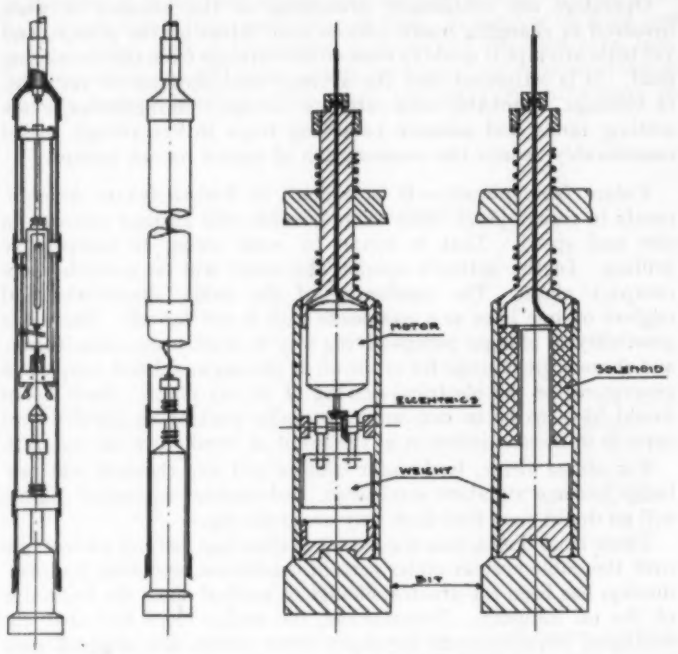


FIG. 41.

Here the bit is hollow and contains an electric motor actuating a vibrating weight through cams. The bit is supported between springs having a vibrating period depending on the motor speed. The bit body is an easy fit in the shoe casing, permitting mud circulation to pass and impinge on the bit teeth. The cable passing up the centre of the drill-pipe would of course have to have mud-proof connections for every four or six joints of pipe.

An alternative design would have a solenoid with a suitable interrupting switch in place of the electric motor.

A design of hydraulic drill is also illustrated in Fig. 41. Here a piston, operated by the mud, picks up and lets fall the bit.

DISCUSSION.

The President said that he was sure members would appreciate the vast amount of trouble which had been taken by the author in accumulating the mass of detail he had laid before the Institution. He did not propose himself to intervene in the discussion, but he would like to compliment the author on his paper.

Mr. A. Beeby Thompson said that the illustrations shown and the descriptions given had been exceedingly clear, and they demonstrated the enormous and rapid advance which had taken place in the engineering side of oil technology. Only a few days ago he found amongst some old papers a catalogue of the original rotary drills (Parker Rotary made at Beaumont, Texas), used in Texas during the Spindle Top boom period, and the comparison of the illustrations of plant of that period with those of present-day machinery made the former look ludicrous.

Early rotary drilling so often failed for the simple reason that the material was not strong enough to resist the stresses applied, and the power was totally insufficient. Until the metallurgists got to work and improved the quality of the material, and engineers realised the immense amount of spare power that was necessary for driving a rig, very little development was made with the rotary drill. A great debt was due to the metallurgists particularly, because without the high tensile steels and special alloys which were now produced the present state of progress in rotary drilling could never have been reached. This specially applied, of course, to the drill-pipe, which was a perpetual source of trouble through twisting off in the early days. The author had not referred to the speeds of rotation of drills. The rotation speed of drills was being increased enormously, and he felt that it was still being limited very largely by the nature of the alloys which could now be used on the cutting edge. He quite agreed that the future of rotary drilling must lie in producing a motive power near the bit. It was inconceivable that they could go on indefinitely extending the length of drill-pipe and drilling lines to a depth of 10,000 ft. and still direct the movements of the bit. At the present moment it seemed almost incredible that these long drill-pipes should give the results they actually did in practice.

He had been interested to see from the illustrations and descriptions the advance made in measures for economising fuel. The insulation of boilers not only caused a great saving of fuel, but also prevented that one great trouble which was found in all fields, namely, priming water finding its way to the engines. Priming had always been a source of trouble in oilfields, probably through using under-power boilers in many cases, but unless

steam lines were properly lagged there would always be a danger of water reaching the engine with consequent heavy knocking, and, of course, a great loss of power.

There was one point bearing on the use of increasing pressures which needed careful consideration in many fields, and that was the question of the quality of water. The use of high pressures necessitated much greater care regarding the quality of the water used in the boilers, for most oilfield waters are saline. Scaling could rarely be prevented with the waters found near most oilfields, and with the high pressures now ruling this might become a very real danger.

Notwithstanding all that had been done in the improvement of drilling plant, the human element is still a factor of concern, and this at present he felt was one of the greatest hindrances to the progress of drilling. The performance of the rig mainly depended upon the operator. The engineer and the metallurgist might give the finest plant and material—and really it must be admitted that much had been done to meet the rough handling of plant—but so long as the operator was careless or unskilful the success of bores is endangered at every stage. Twist-offs, as everyone knew, were a constant source of trouble in almost every field, and if one read the account of drilling, in Alberta, for instance, where the difficulties are great at the present moment, one realised what a great deal there was to do yet before a satisfactory complement of drill and driller could be obtained. In other fields, like Rumania, the same troubles were being faced. The finest plants of the very latest design with the best tools were being handled in many parts of the world somewhat roughly by inexperienced or inconsiderate operators, and often only failed to give that satisfaction which might have been anticipated through lack of judgment in handling. He thought that while engineers were spending so much time in the design of plant they were in danger of neglecting the perhaps more important matter of training the personnel, and without the skilled personnel the hoped-for advances in rotary drilling would be delayed.

Mr. L. J. Wilmoth said there was one point in regard to rotary pumps on which he would like to add a word. Although not a drilling man, he was very much interested in getting holes down. The point that occurred to him was with regard to the wear and tear caused by the chips and cuttings that came up with the rotary mud, which had always been such a great problem. It seemed to him of the greatest importance to eliminate, as far as possible, all coarse material from that mud before it was returned to the hole. There were two reasons for this. First of

all, the purer the mud the better were its cementing properties for holding up the sides of the well. Secondly, there was great economic value in eliminating wear and tear and reducing the cost of the upkeep of these pumps. Two or three months ago he was giving quite a great deal of thought to this problem, and an idea had occurred to him. Before he went into the oil industry he was a mining man, interested in the metallurgical rather than the underground side. If one had had experience of modern gold metallurgical plant with stamp mills, and so forth, one would know that an outstanding feature was the classification scheme for the separating out of slimes. At the time that he left mining a system was employed which involved a hydraulic classification by a series of cones, and he would make the suggestion to the engineering and drilling people that perhaps they might do well to give some thought to the application of this old metallurgical method of classification.

If the mud were taken as it came straight from the hole it might be reduced down with water until a sufficiently thin fluid were obtained, very similar to that leaving the bottom of the amalgamated plates in the stamp mill. This would permit of separating certainly anything plus 60 mesh. It would take all steel and all chips. If that were fed into the centre of a cone with an annular discharge the coarse material could be taken from the bottom and the result would be an annular flow of a very thin mud. With another cone having a diaphragm a third of the way down the mud could be thickened to any point desired and returned to the pumps as a perfectly clear mud, free from the unpleasant cutting material which was now so often found, and infinitely more efficient for the purpose for which it was required. He had not had time to work out this suggestion, but he was seriously proposing to do some experimental work on these lines when he got back to the field in a few months' time. He thought there was probably something in it economically and from the technical point of view, and certainly worth while the engineers giving it some thought.

Mr. J. Gillespie drew attention to the fact that in this paper, closely and very thoroughly detailed, the author had dealt only with one portion of the drilling of oil wells from the engineering side. There was still all the underground operation to be dealt with. Even with the surface work he had not dealt exhaustively as his reference to electrical operation was designedly merely incidental. So wide is this engineering side of the Petroleum Industry that it is worthy of many such papers. It is all to our advantage that these detailed communications should appear in the Institution's records.

He had been much interested in some of the excellent illustrations given. While Mr. Matheson was showing the steam drilling engines of to-day the speaker's mind went back for 20 or 25 years to an afternoon when he was inspecting one of the first steam drilling engines ever made in this country. He had an experienced driller with him, and to him he remarked : " Yes, it is very good and very substantial, but what about lubrication ? " To which the driller replied : " Don't you know that the driller draws from another well a bucket of crude and throws it over the engine occasionally ? " There was nothing further to say to that, and he had been pleased to observe that evening that the question of lubrication had been carefully attended to, and that roller bearings, bronze bearings and other improvements in the same direction had developed very greatly since that day.

Although to some extent he was interested in the production of oil well tools in this country, he hoped he might be forgiven for saying that he was delighted to see how often English design and production were mentioned in the paper.

Dr. J. A. L. Henderson said that the paper had been a very clear one, particularly on the mechanical side, and he agreed with what Mr. Beeby Thompson had said in regard to the need for better training of the men who were now required to take charge of the high-class engineering problems which modern oil well drilling connoted. He had but one general remark to make, and that was with regard to drilling in the future at great depths. The attention of all those interested in drilling had for very many years past been occupied with the possibility of applying power at the bottom of the well. The illustrations given in the paper dealt with the hydraulic and electrical types suggested. The speaker thought that the most probable chance of success, if the danger of an explosive mixture with natural gas could be overcome, lay in the use of pneumatic methods, on the lines of the well-known pneumatic rock drills used in mining. That principle might be very well tested out thoroughly, and he saw no reason why a workable automatic pneumatic drill should not be evolved.

Mr. W. R. MacDonald said that the paper had given a great deal of useful data, and the few remarks the author had made at the end in connection with the development of drilling were also most interesting. He had himself made a study of one or two aspects of this subject, and he was sure, only from a scientific standpoint, that if the author continued his research a little further he would find the study most entrancing. The application of a power-driven unit at the bottom of a long drill-pipe or steel rod

was full of possibilities. One of the difficulties in deep drilling, apparently, was the keeping of the rotary drill straight. Scarcely any research was needed as to why the drill should wander, as it seemed to him that a long rod with a cutting tool at the end of it could not be expected to bore a straight hole indefinitely. With a high percussive power unit at the bottom of the steel rod requiring little torque to turn it, the possibilities of wandering might be avoided and one should then get practically a straight hole. He did not see any great engineering difficulty in arriving at a method by this means which would enable the drill to get down to very deep levels. A little conservatism might be holding things back, but a time would come it seemed to him when deep wells might be obtainable by relatively cheap methods.

Mr. Alexander Duckham said he spoke as one who had commercial rather than technological experience of oilfield work. What the author had said about the misuse of plant appealed to him tremendously. It was sad when one went on to an oilfield to note the ignorance and cruel treatment with which the operator often used his plant. In justice to the British driller he was happy to say that it was his experience that, just as the British people were known the world over for their kindness to animals, so they were far more solicitous regarding the welfare of their plant and tools than were the operators of other nationalities.

He would have liked the author to go further, because in his own experience he found that drilling the hole to target depth was generally a comparatively simple matter—he was speaking of depths of 2,000 to 3,000 ft.—but, when the hole had been drilled, it was necessary to make it a steady producer, and that was the difficult stage—calling for imagination, experience, confident decision and suitable material.

He had been fascinated by the matter, and the peculiar grip of his subject shown by the author. It was a pleasure to have such a paper from an Associate Member, and he hoped others would be forthcoming.

Mr. Niels Matheson, after thanking the members for the complimentary way in which his paper had been received, said that Mr. Thompson had raised a point which was very interesting, namely, with regard to the power necessary. Very few realised that if an engine had got to take so much steam, and a pump had to take so much steam, a boiler generator was required equal to more than those two combined loads.

He agreed with Mr. Thompson's remarks about the metallurgist's work. A great deal of work had been done and was being done at

the present moment in the direction of giving better materials. He had tried to show how cast iron was giving place to new types of steels. That was all on the right lines.

Economy of fuel had also been mentioned. He agreed entirely with what Mr. Thompson had said about water and water softeners. The water question was always one of great difficulty. It was not only a question of water being available in particular areas, but the greater difficulty was the frequent scarcity of good water with the resultant rapid scaling up of the boilers. He remembered how different waters had affected boilers in Burma. The river water deposited scales rapidly, whereas water from certain water wells had a cleaning effect on the boilers. Boilers scaled up by the river water and transferred to another field were very conveniently cleaned out by the action of the well water.

With regard to the human element, he was afraid this would always remain while drillers appeared to go after footage rather than ultimate results. Mr. Thompson had spoken of drillers who did not really know their job. He remembered, also in Burma, a story of one driller who said, when on his first rotary plant, " Well, here I am. I have not done much damage up to the present on cable wells, but I am liable to do a lot within the next few minutes on this funny outfit ! "

The removing of the cuttings from the sumps, as mentioned by Mr. Wilmoth, was very important, and he would like him to put his suggestion forward in greater detail for the benefit of those who were not conversant with this metallurgical method of classification.

He would also like to thank Mr. Gillespie for his remarks, and to say that he was sorry that he had been able to deal only with one portion of what Mr. Gillespie rightly said was a large subject. He had dealt only with the question as it applied above the derrick floor. He had particularly headed his paper " Some Features of Steam Operated . . . " because there were certain matters which he must leave alone if his paper was to be brought within reasonable compass. The question of electrical drive was a subject for a paper in itself.

Dr. Henderson's remarks on bottom-hole powered drilling were very interesting. His suggestion of a pneumatic method had been often worked out, but the speaker thought that this method would involve a triple pipe. One for inlet air under high pressure, one large exhaust air pipe in order to reduce the back pressure on the motor to a minimum and the third pipe for mud circulation. This made it a difficult proposition. Nevertheless he liked the idea immensely.

Mr. MacDonald had spoken about the rotary drill not going straight. The rotary drill certainly would not go straight even

if the power was at the bottom of the hole. He believed it was, in fact, apt to go more crooked in that event. He would be interested to hear more of those types of drills which Mr. MacDonald mentioned as being at work at the present moment.

He thought that Mr. Duckham's remarks on the misuse of plant were very important. He doubted whether in the last six years he had seen a drilling well which was really run in what he woud think a sound manner. The general idea seemed to be that one either worked for one's dollar or one's footage, but one rarely worried about the condition of the plant. The advent of the British driller with his greater care for the plant should considerably increase the plant's life. But his impression always had been that a man who drilled seemed to think it beneath his dignity to have to apply to a "swivel-chair engineer" to help him out in the maintenance of his plant. He would rather leave it as it stood until too late and then send in a chit to the effect, "I am all blowed up." This expression might mean anything from a nut gone loose, or a slack big-end, to the rig pulled in, but whatever the trouble was, cure rather than prevention seemed to be the order of things. The more he saw of drilling the more he felt that the subject of suitable plant must be tackled bit by bit, and hence in this paper he had not gone below the derrick floor, except to show how the application of the power at the bottom of the hole would completely change the above surface conditions. As it was, he felt that he had tried to tackle too much. The questions of bringing in a well, drill-pipe, controlling appliances at the well head, fishing tools, etc., made the subject such a big one, that that must be his excuse for the partial treatment he had given to the subject that day.

He wished to add that, since waiting the paper, the production of the swivel, having the long wash-pipe with the bottom gland, had been discontinued and the makers had now introduced a swivel of the short pipe type capable of running at 100 r.p.m. with a load of 150 tons.

A vote of thanks was accorded to the author, and the meeting terminated.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

THE ONE HUNDRED AND TWENTY-EIGHTH GENERAL MEETING of the Institution of Petroleum Technologists was held at the Royal Society of Arts, John Street, Adelphi, London, on Tuesday, May 13th, 1930, the President, Dr. A. E. Dunstan, occupying the Chair.

The Secretary announced that the members elected and the persons nominated for election since the last General Meeting were :—

The following have been elected:

As Members.—David Allan, Henry M. de Cizancourt, Robert Crichton, Paul D. Foote, Leon Iacovitz, Richard Henry Thorburn Jobson, Alexander Reid, Alexander Walker.

As Transference to Members.—Harvey Satchell Garlick, Charles Ignatius Kelly.

As Associate Members.—John William Amner, Edgar Beardsworth Fox Auld, Vincenzo Damiani-Lugaro, Robert Hugh Dolton, Edward Leslie Gent, John Harry Maltby, Horace Edward Newton, André A. Perebinossoff, Hugh Charles Tett.

As Transference to Associate Members.—John Wardlaw Reid.

As Students.—Walter William Scott, Thomas Speight, Joseph Edwin Walker.

As Associates.—Hugh Peregrine Henzell, Frederick Caulfield-Kerney, John Macdonald, Clarence Achilles Palmer-Chizzola, William Sigsworth, Henry David Thom.

At the Council Meeting held on April 8th, 1930, the following were nominated :—

As Members.—Robert Allan, Louis Alfred Bushe.

As Associate Members.—Almon Lee Beall, Harry Dobson, Raymond Wilson Dunster, Max Metsch, Donald Gray Phelps, Terence Charles Richards.

As Transference to Associate Members.—William Edmund Madden, Ian McCallum.

As Students.—Herbert Harland, Robert Edgar Moore.

As Associates.—William Henry Bailey, George John Hancock.

At the Council Meeting held on May 13th, 1930, the following were nominated :—

As Transference to Members.—Francis Roger Spencer Henson, Niels Matheson.

As Associate Members.—George Barclay, David Neill Mckinlay, Kenneth Arthur Spearing, Arthur Augustus Weir.

As Transference to Associate Member.—Donald Thomas Jones.

As Student.—Willem Jan Hessels.

In the absence of the Author, the following paper was read by Capt. D. Comins :—

Oil Well Deviation.*

By D. P. Rees, A.R.S.M. (Associate Member).

A problem of primary importance to all field branches of the oil industry is that of the divergence of wells from the vertical. Until comparatively recent years, although carried as an established fact, serious steps were not taken either to remedy its effects or to cure it at its source.

While it must appear obvious to the layman that holes drilled in the various sediments associated with oil deposits cannot adhere to a geometrical straight line, even an approximation to that ideal is seldom obtained in drilling practice. With deep holes, the problem becomes more intense and difficult of solution, the factors governing the divergence being accumulative, and the outfits designed to handle greater loads and capable of increased drilling speeds tend still further to deflect the bit, unless suitable precautions are taken. Taking the crooked hole as unavoidable, the only means of dealing with it are (i) to reduce the deviation to a minimum, (ii) to measure that deviation as accurately as field conditions permit, and (iii) to apply the information so acquired to the calculations of the geologist and the technical branches of the field staff.

In an established field two lines of attack are open in dealing with the problem :—

(1) To survey every hole, whether producing, non-producing or drilling. This entails considerable alteration to company records and introduces serious difficulties in wells of small diameters.

(2) To modify existing records by running surveys on drilling wells only. This is the method generally adopted, as there is less shut down time and the surveying instrument can be run at regular intervals on the drilling string.

The problem of keeping straight hole is one which has been discussed at considerable length by the mining world in connection with diamond drilled core holes, and valuable data and conclusions are available from the mining records.

It may be suggested that the labour and expense of surveying holes and applying the calculations to field records will not sufficiently affect the production to make it profitable, but when all the points affected are considered—the estimate of future pro-

* A précis of this paper will will be found in Abstract No. 734.

duction, volume acreage of the sands, structural boundaries, dry holes in productive surface areas, well spacing, repressuring problems and generally incorrect subsurface information, besides technical problems on both drilling and production sides—it should be obvious that the matter is too deep rooted to be ignored, and if it cannot be definitely eradicated its extent must be known.

The old-timers' maxim of "oil at any cost, no matter what shape the hole," cannot be accepted by the more efficient producer of to-day. Structures formerly abandoned after cursory drilling inspection may prove productive when the holes are shown to be so crooked as to have missed the pay sand completely.

Deviation. Main Considerations.

A. Geological.—In testing a new area the exploratory well should be drilled with the greatest care to minimise deflection. Subsequent holes can afterwards be more easily correlated and local irregularities in the structure will not be missed.

At regular intervals the hole should be surveyed and a log kept of the readings. The log should give the depth of the reading, the deviation, azimuth of the deviation, corrected depth and horizontal displacement on lines indicated in the following table :—

Reading.	Depth.	Inclination.	Correct Depth.	Azimuth.	Horizontal Drift.	Remarks.
A	B	C	D	E	F	Average weight on bit.
			B cos C		B sin C	Type of bit, etc.

From the well log can be ascertained such particulars as formation drilled, size and type of bit and drilling speeds, which will afford great assistance in discovering causes of sudden deviation. In wells where the deviation is considerable a curve of depth : corrected depth may simplify calculations.

The importance of these readings is demonstrated in core correlations. In monoclinal dips of small extent a general inference from a number of wells may be sufficient, but more definite information is required in more complex structures. The problem is the application of the principles of solid geometry, and resolves itself into the intersection of an inclined plane (dip) with an inclined cylinder (the course of the well).

True depth of the core is of primary importance, but unless the direction of deviation is known no information can be gained from the dip of the core. An inclinometer containing a recorder of azimuth is, therefore, most necessary from a geological point of view.

In dips of considerable extent any large divergence from the vertical will tend to make the well travel with the structure and it may miss the pay sand altogether. Means may have to be taken to force the hole to regain its original course. (See below: Correction.)

Surface well spacing, although vigorously enforced in most fields, cannot give a true idea of subsurface interval, although it will naturally tend to give more efficient drainage conditions, and may be most convenient at surface for roads and engineering services. This being realised certain sums may be saved in large grades, difficult roads, etc., by altering the well interval slightly.

Again, should a well be found to deviate towards a proposed location, this latter may be respaced to avoid interference at depth.

Casing programmes must be altered to suit the modified conditions. Failure to shut off certain thin water sands may be attributable to the fact that a previously calculated depth for the sand has not allowed for the modified depth of a crooked hole.

In restricted areas, where competitive drilling is carried on, the use of the directional inclinometer may disclose instances of holes which have transgressed surface boundaries and may introduce litigation.

For this reason the running of directional surveys may not prove popular with individual producers, but the ultimate effect will be a tendency towards straighter hole with fewer attendant difficulties, and will be for the better development of the pool with more efficient ultimate extraction.

Such surveys might be left to government engineers or run by co-operation among the producing companies under similar conditions to those that have met and coped with the problems of boom drilling, unrestricted production and the race for naval supremacy.

B. *Technical.*—The technical view point centres on modifying drilling technique to reduce deviation to a minimum, since, although the pay may be penetrated, subsequent drilling and producing difficulties may turn a good well into a poor business proposition.

The detection of crooked hole may be difficult Unless the well is surveyed at frequent intervals and unless the fault is remedied immediately, considerable time is wasted in subsequent reaming operations.

The trouble, although not wholly confined to the rotary, is there most marked, and as that system is more and more displacing cable tools, this paper will in the main apply to rotary drilled holes.

Since the object of the surveys from the technical side is mainly detection, the orientation of the reading is of secondary importance

although it might disclose some of the causes of error which might be more successfully tackled ; *e.g.*, side-tracked pipe which has led to sudden deflection of the hole.

Crooked hole will be more easily detectable when the change from the vertical is most abrupt, the sudden bend will impart a jar to the drill-stem when running in, and if reaming is started before the ledge is spoilt, the difficulty of starting new hole will be minimised.

A gradually increasing inclination may be imperceptible on the derrick floor until the production phase. This emphasises the need for systematic surveying of the hole from the start.

Unless there is a sudden deflection which will readily afford a shoulder on which to work, reaming will be very slow and the prolonged circulation up in the hole will induce extensive caving. It has been proved that reaming on a slight inclination does not pay, so that unless there is a definite obstruction the hole has to remain crooked.

Plugging the hole back with cement will offer difficulties in subsequent redrilling, as the hard obstruction, unless very carefully approached, will lead to a sudden alteration in the course of the hole, not always in the required direction.

Crooked hole will cause irregular wear on various parts of the drilling outfit, resulting in eventual breakage. Twistoffs will be more common, difficulties in handling pipe and casing troubles will occur, while in the production phase worn and broken rods, tubing, etc., will be daily happenings.

In drilling, some of the effects are cumulative. Should a twist off occur and the tools be buried, prolonged circulation in washing over may enlarge the hole and the fish may fall over to the side and the only solution becomes side-tracking. Where the bit meets the fish there will be an increased deflection with correspondingly accentuated difficulties.

Lost circulation through intersecting holes and lost production through such intersections are examples of wells carried down without sufficient attention being given to the question of verticality.

The extent of deviation can best be realised by the citation of a few examples.

R. Van Mills in the *Oil and Gas Journal* of August 23rd, 1928, instances the case of two wells in Oklahoma which were spudded in within a month of each other. The surface interval was 112 feet and no attention was apparently paid to the necessity of keeping straight hole. After several days of record footage the second well intersected the first at 1685 feet and had to be plugged back and junked.

The same writer gives another even more arresting example of waste hole in Seminole. Two wells were spudded in 660 feet apart and met at an approximate depth of 2,500 feet.

Instances of lost circulation in drilling holes with near-by producers giving sudden large quantities of drilling mud are common, and provided the surface spacing is correct and that abnormal subsurface drainage channels do not exist, interference must be due to transgression of one or both the holes.

While actual intersection is not so common, the amount of lateral drift of rotary drilled holes can be realised from a study of any reports of such investigations such as those of A. Anderson, whose Oil Well Surveying Apparatus is in extensive use in America. In his survey of Olinda, No. 96, the hole at 3,575 (measured depth) is 316 feet from the vertical through the derrick floor. At 6,000 feet this increases to a maximum of 517 feet. Such figures are by no means exceptional.

D. R. Snow in a paper read before the Tulsa Geological Society estimated that $2,000,000 had been spent on unnecessary hole in the Seminole area, due to loss in depth consequent on deviation.

The greatest recorded vertical correction in this field was 798 feet in a total depth of 4,000 feet. At $7·00 per foot this amounts to a sum of $5,586·00. With casing, fuel, water and depreciation the total loss on this hole due to deviation would not be far short of $10,000·00 or about 20 per cent. of the cost of the hole.

Drilling Practice.—Correcting the fault at its source applies to crooked hole as much as to any technical problem, and the field operator who is closest in touch with the actual difficulties is best able to afford information which can be compiled to give a new technique in drilling operations.

Much useful data appears in a paper in the *Oil Weekly* for June 7th, 1929, where the author summarises the results of a questionnaire submitted to rotary drilling contractors in the Greater Seminole area.

Opinions appear to differ regarding the usual course followed by the bit. Hudson and Taliaferro[3], from observations made on McFarland No. 1 Well, deduce that changes in lithology, due to the clockwise rotation of the drill-stem, induced clockwise changes in deflection, but that mechanical difficulties such as side-tracking usually deflected the bit in an anti-clockwise direction. This well was drilled through sedimentary rocks of Pliocene and sedimentary and volcanic rocks of Miocene age, and the lithological changes were well marked by considerable changes in azimuth and to a less degree in inclination. The anti-clockwise changes due to mechanical agencies were believed to be fortuitous, though it is noted that such a change at 2062 feet in basalt and brown shale

cannot be attributed to any mechanical agency, as no trouble was experienced. Lumps of basalt, however, were continually falling in and jamming the bit and would have a somewhat similar effect to iron in the hole.

A contrary experience is related by A. Anderson,[4] whose survey of Olinda No. 96 showed that the course of the well was on the whole anti-clockwise irrespective of changes in lithology or fishing jobs.

It appears that no general conclusions can be drawn, but that each well offers its own particular problem solvable by the man on the spot.

A few remarks on the behaviour of the bit under certain conditions will serve to show the tendency towards deviation.

In gently dipping beds the fish-tail bit, on striking a shell, will tend to meet the surface at right angles, and in doing so will deflect the drill-pipe in that direction—*i.e.*, up dip.

In steep dips the resistance offered to the bit is still on the up-dip side, but on exceeding the critical angle the wings of the bit are deflected away from the face and tend to wedge down dip. This critical angle at which one would expect the hole to be unaffected on entry into the shell is naturally not determinable, the feed and local conditions determining the course of the bit.

Where the bit, drilling without reamers, strikes a shell, a certain amount of triangulation of the hole may result which will offer considerable casing difficulties, and will increase the chances of going off the straight.

The bit does not necessarily rotate on the drill-pipe as its axis. In argillaceous beds, bits of 15 ins. diameter and upwards become wedged against the side of the hole, and the spiral motion imparted to the drill-pipe causes the bit to cut an annular hole. The core left in the centre will cause serious trouble unless removed. While not easily detected in drilling, this coring is evident by examining the bit on withdrawals. The core will leave its mark on the centre line of the bit, extending, if the coring has been continued for any length of time, to the drill-collar. The edges of the reverse side of the bit become worn to the shape of the annular hole.

If the drilling is soft, light spudding will generally effect a cure. Otherwise a rock bit must be run lightly until the core is broken down and any tendency to deviate is stopped.

Deflection of the drill-stem is dependent not only upon the weight applied but also on the size of the hole. If this has been increased by prolonged circulation with thin mud in caving formations, the drill-pipe, losing the support of the walls, will tend to maintain a bow. Even if this set is not permanent an eccentric motion is imparted to the bit.

Spudding a bit on a shell will almost certainly result in bent pipe or, what is worse, a bent drill-collar, and should be strongly discouraged. In sticky drilling the bits should be cleaned by rotating upwards, and spinning rather than by heavy spudding.

Incorrect centering of the hole when coring or starting in with a smaller size bit will also tend to start eccentricity, and centering with diamond-point bits of full gauge or the addition of full size reamers to the string temporarily would appear to be best practice. Prolonged drilling, however, with diamond-point bits, or bits which have been badly worn or badly dressed, is a fruitful cause of the start of a crooked hole.

Drilling in homogeneous country where the dip is not considerable does not offer such serious difficulties, and the hole can be kept within reasonable limits of verticality by judicious regulation of the feed and speed of rotation. Even in such cases, at the various depths at which casing must be set, situations obtain which, unless carefully handled, may lead to loss of verticality. Particularly when the pipe is cemented, an almost invariable rule in current practice, extreme caution must be observed on going ahead with a smaller drilling string. The bit, if forced through the plug, will take the easiest path, which will be found in the majority of cases to tend to one side of the pipe. Hence, the sudden changes in deflection which usually follow the cementing of a string of casing. The solution would appear to be the careful drilling out of the plug with rock bits.

Spudding In.—If cable tools are used for this purpose the problem of getting a good start is greatly simplified, as unless boulders or steeply dipping shells are met with, surface pipe can be cemented in vertically. If crooked, a light lowered down the hole will indicate the fault, and plugging back and redrilling will generally effect a cure. Where rotary is used for starting the hole, Mid-Continent operators take extreme precautions to avoid any settling of the derrick foundations; the structure is plumbed, and in installing the outfit the table is lined up accurately with the derrick centre, levelled, and the drilling hook again plumbed with the table centre after the lines are strung.

Some means of guying the Kelly to keep it rotating vertically is normal practice, and the alignment is checked every two or three feet down until there is sufficient weight below the floor to keep the swivel from rotating eccentrically. The weight is kept well up, and the speed of rotation adjusted to check any tendency towards eccentric motion.

A load indicator is most necessary to give the driller information as to the most efficient feed, and can be calibrated by any operator

after a short experience of the instrument. The personal equation enters so largely into drilling operations that any hard and fast rule as regards loading is liable to be misused, particularly over fields of considerable area, and even two adjacent wells may call for entirely different handling.

The sensitiveness of the indicator is greatly increased by attending to the oiling of the dead line crown sheave, and compensating links should be fitted to the unit containing the diaphragm to avoid distortion of the load diagram.

Bits.—It appears that the best results have been obtained by running rock bit throughout the period of drilling, self-cleaning cones being generally adopted where there is a preponderance of clays and shales. The bits themselves have more rigidity than a fishtail or disc bit, and the cutting or grinding action does not tend to give eccentric motion. The K.P. bit is also used with considerable success, and makes more progress than rock bits in gumbo country where there is little or no arenaceous medium to mix the cuttings properly.

The Imperial Oil Co., in Turner Valley, Alberta, a field recently visited by the writer, employ K.P. bits very largely to about 2000 ft., where a change is usually made after cementing the first string of casing to S & H rock bits, which are able to maintain good footage when the lime is penetrated. Although the dips in this region run as high as 35° to 40° little trouble is experienced with crooked hole. Halliburton drilling control is in use on practically all the rotary rigs, and does away to a certain extent with the personal factor.

If fishtail bits are used, borium or some hard facing is desirable, as the tendency towards crowding is very strong when the bit rapidly becomes dull after drilling tight on a sharp sand. The wings of the bit receiving most wear gradually assume a diamond point, which in the writer's opinion is a fruitful source of the hole diverging owing to the wedging tendency. Fishtail bits should be carefully examined before running to see that they are full to gauge at the points, and as soon as excessive weight is required to maintain drilling speed the bit should be pulled.

For this reason rock bits are preferable, as the maximum amount of metal is at the base of the cone. It has, however, been observed that the base is slightly cut back by the manufacturers in the latest self-cleaning cones. This will not give the same wall-holding properties as would appear to obtain in true cones.

If the rock bit runs with a slight percussive motion the weight should be decreased. The probability is that the bit has met with an obstruction on one side of the hole and is tending to drive its

way in the easiest direction. If the bit is raised, cleaned and again run very easily until all tendency to jump has ceased, the best entry of the shell will have been effected.

Disc bits while giving increased footage in homogeneous sandy shales are liable to set the hole off by reason of their contour which approaches that of a diamond point bit. In the writer's opinion the crooked hole hazard is increased by their use in country rock containing irregular hard patches or boulders.

Stiffening of Drill-Stem.—The chief cause of crooked hole is, as has been mentioned above, the bending and whipping action of the drill-stem. When the length-diameter ratio of 6 in. drill-pipe at, say, 4000 ft. is compared to that of a silk thread by responsible operators, it is obvious that the stiffening of the whole by adding to the section internally will only slightly influence the situation. Extra heavy pipe again will be more liable to rapid crystallisation and fracture. Although the employment of 8 in. drill-pipe for spudding operations is to be commended, at depth delicacy of feed and local stiffening of the drill-stem near the bit will be more effective.

Various means of achieving the latter have been tried. A number of drill collars connected together directly above the bit and increased size of collars up to 9½ in. O.D. at 200 lb./ft. have effected an improvement.[5] Mid-Continent operators appear to favour triangular roller reamers, and the wells so drilled averaged 2½° off vertical compared to others drilled in the same territory without reamers which were from 3° to 9° off.

In Burma current rotary practice favours the running of 200-400 ft. of 8 in. ×40 lb. drill-pipe next to the bit.

Reamers.—In some cases the use of smooth rollers has prevented the walls of the hole from being disturbed and losing their mud content, while the serrated rollers tended to increase the size of the hole and cause caving.

Other methods of ensuring a straight course for the drilling string include double decked three point reamers which are run 20 ft. from the bit, and a special reamer which works within 3 ft. of the bit.[5]

Above the reamers is occasionally run a joint of 8 in. pipe perforated to allow return circulation and fitted over the 6 in. drilling string by heavy swedge nipples.

The additional weight so applied to the bottom of the string enables the bit to be more efficiently loaded without the necessity of allowing the upper part of the drill-pipe to bear on the string, thus causing bowing of the pipe and the loss of the straightening effect of the gravitational pull.

When the bit leaves the vertical, however, this additional weight acting at such a small angle to the force of gravity will have very little corrective effect.

The drill-collars and reamers should be frequently checked as to straightness, this applying also to drill-pipe in general. Any kinks or bends should be eradicated by replacing with a new collar or all attempts at straight drilling will be useless.

Mud Flush.—The weight of the circulating fluid should in general be sufficient to keep the hole reasonably clean, as cuttings otherwise may settle to one side and lead to eccentric motion of the bit. 80 lb. per cub. ft. is a reasonable weight to maintain in all but mud making shales and clays, and should be frequently checked by weighing.

Where the walls of the hole are liable to cave under the influence of the pump action the weight of the fluid should be brought up to at least 85 lb. per cu. ft. and the rate of flush reduced to a workable minimum, otherwise the supporting action of the walls is lost. This applies particularly to cases such as starting in on a shell or a fishing job which may necessitate prolonged circulation.

The practice of spudding in with water is to be deprecated, and experience has proved that holes started with good mud are generally straighter than others where less attention has been paid to the circulating fluid.

Flush-holes in bits should be bored so as to prevent gouging action of the walls. Here again rock bits are an advantage as flush emerges between the cutters.

American operators favour larger and still larger pumps. The standard size is now $14\frac{1}{2} \times 7\frac{1}{2} \times 18$ working at 220 lb. steam pressure. When the circulating fluid is carefully watched this does not induce extensive caving, and the holes so drilled do not appear to suffer any loss of verticality.

The general opinion appears to be that speeding up the pumps does not affect the verticality of the hole unless caving is started.

In this direction it would be extremely interesting to note the action of a drilling string rotating in a mine shaft where conditions analogous to those of a badly caved hole would obtain,

General.—When the seriousness of the problem was first realised an attempt to limit deviation by restricting footage was made. This policy was abandoned when it was seen that more harm could be done to a hole in 5 min. by attempting to force a bit through a shell than by drilling 100 ft. in sandy shale in an 8-hour tour.

Unless the hole has caved extensively an increase in the rotational speed should have a steadying effect on the drill-stem.

Outfits have been designed to give table speeds of 127 to 175 r.p.m. for 15 in. bits, and still higher speeds for smaller sizes.

This naturally reduces the maximum permissible weight on the bit and great delicacy of feed is necessary, but as long as there has been no caving tendency there will be less likelihood of a fracture owing to the closer approximation to the ideal straight line.

Differential Control.—The mechanical principle of the differential has been applied to drilling with a certain amount of success. The prime mover, steam or electric, drives the differential and the torque of the drill-stem is balanced against the load on the bit. Unfortunately the manufacturers have not been able to adjust the two variables to allow for constantly increasing weight of drill-pipe with depth.

The combinations of gears which actuate the hoist in one type are only suitable for certain loadings. Outside these limits the hoist will be either overgeared or undergeared, the balance will be destroyed, and the bit loading will not remain constant. Hand feeding to supplement that of the differential has to be resorted to, which does away with the advantages of the automatic feed.

What would appear to be the ideal as expressed by W. R. Cummings in the *Oil and Gas Journal* of September 13, 1928, is the introduction of a variable gear on the hoist side of the differential under the driller's control, enabling him to regulate the hoist to suit the dead load on the hook.

When the strata drilled are unhomogeneous, boulders and hard streaks will cause a percussive action of the drill-stem, due to the delayed action of the differential. This will increase the tendency of the bit to sidetrack the obstructions and must be corrected by damping with the brake, should a lower gear ratio prove ineffective.

Detection.

Various methods have been employed to detect deviations of wells from the vertical. The question has been discussed at great length in mining circles, and instruments of comparatively high degrees of accuracy have been employed to survey diamond drill holes.[6]

The petroleum industry to-day stands in need of an instrument capable of easily and cheaply surveying the course of the wells. The acid bottle, the most popular present-day method, in its simplest form only affords information as to the vertical error, and although there are numerous successful instruments which give a complete survey of the hole, their general adoption is impracticable on account of expense, fragility and possible infringement of copyright.

Inclinometers.—The principle of most inclinometers is the recording of a liquid level relative to the sides of the hole. The most popular perhaps is the acid bottle method, in which a sample bottle of 1½ in. internal diameter is half filled with a dilute solution of hydrofluoric acid : 25 per cent. concentration will etch the sides of the bottle sufficiently to give a reading in thirty minutes. The bottle is run in a special container, and allowed to remain at the test depth for a predetermined interval. On withdrawal the deviation is measured by the formula :—

$$\frac{h-l}{d}\times 100 = \text{deviation per 100 ft.}$$

where h=high side of etched ring.
l=low " "
d=int. diameter of bottle.

Or by means of a protractor.

The error in this instrument is 2 – 5 per cent., but may be slightly reduced by applying capillarity curves to the calculations. A method formerly employed by a number of companies utilises mud fluid, which is allowed to come in contact with a roll of paper wrapped round the internal 3-in. pipe of the 6-in. inclinometer body, which is inclined parallel to the walls of the hole. The mud is caused to rise either by displacement due to insertion of a mandrel or in the open-ended type of inclinometer by the compression of a small quantity of air in the upper part of the instrument as the inclinometer is lowered. On withdrawing the inclinometer the paper is unrolled and the reading taken from the amplitude of the wave. Although this is not strictly proportional to the deflection, for practical purposes an amplitude of 1-16th in. is taken as 1° off.

Other forms of inclinometers utilise pendulums which are photographed at the desired depth by clockwork timing devices or by depressing a key at surface. In another instrument a quantity of mercury in a bath fitted with electric contacts gives a galvanometer reading on being tilted, the contacts forming the variable arm of a Wheatstone bridge. These instruments are in common use in modern practice, but all possess the disadvantage of giving only the amount of deflection. As the azimuth of the deflection is all-important geologically, various means of orienting the instruments have been devised. The majority of attempts to fix the orientation of the inclinometer rely on the rigidity of the drill-stem when run in the hole.

A telescopic sight is clamped to the top of each stand of pipe as it is made up and sighted on a distant object. When the pipe is lowered the telescope is again sighted on the same object. As the pipe is suspended on the ball-bearing Wigle hook, any tendency to turn can thus be noted and corrected. When, however,

the length-diameter ratio of a 5,000-ft. string of pipe is taken into account, it appears doubtful whether any tendency to twist will be visible at the surface. A more satisfactory method is to fix the orientation of the inclinometer at depth by means of a compass needle or gyroscope.

(*a*) Examples of the former are the Maas compass, where the needle is fixed in position at a predetermined time by the solidification of gelatine; Oehman's apparatus where the compass is photographed; and the more recent invention of A. Anderson, which has been widely used in California.

Extraneous magnetic influences are obviously the controlling features of this class of instrument, and if such exist to any extent readings will be valueless. It has been observed, however, that magnetic ore bodies are not generally met with in petroliferous areas. Cased holes are, however, another matter, and it is doubtful whether the claim that magnetic influences are concentrated in the ends of the string can be substantiated. A needle suspended inside casing will only remain unaffected if the casing is quite uniform, and the point of suspension is exactly in the centre. Otherwise the earth's lines of force will be deflected in the interior of the pipe and the needle will not be correctly oriented.

The lowering medium, whether drill-pipe or steel line will, if truly vertical, only affect the needle in the vertical plane—*i.e.*, cause it to dip without affecting its azimuth other than by bearing friction. If, however, the hole—and consequently the lowering agent—is inclined the horizontal component will affect the needle and give an incorrect reading. To overcome this the inclinometer can be lowered on a length of non-magnetic stem (such as brass) which will insulate it magnetically from the influence of the lowering medium. It has been found by experiment that 10 ft. is sufficient to separate the instrument from such disturbance. If extraneous influences are suspected at any point in the hole, two or three readings taken a few feet apart at the desired depth will considerably reduce the possibilities of error. The most simple combination appears to be that of an acid bottle with a compass needle mounted below in a brass container, away from any possible magnetic interference of the lowering medium. To preserve the orientation of the bottle relative to the compass, the container must be inserted on guides.

(*b*) Gyroscopic inclinographs include (i) Martienssen's instrument which employs two pendulums at right-angles and a gyrocompass which orients the housing in which the pendulums are fitted. The whole is lowered by a cable incorporating insulated conductors, and the readings are taken by depressing a key. Each

pendulum is photographed on record paper separately. Several other gyroscopic instruments have been devised but have the common disadvantage of high cost, fragility, and small size of the gyroscopes. In measuring the inclination of wells of small diameters these drawbacks are accentuated.

(*c*) A third method of determining the position of the hole at any desired depth, without the necessity of taking continuous readings from the surface makes use of an electrical seismograph. The detector is set at the desired depth and small charges of dynamite are exploded at the four cardinal points of the compass relative to the well mouth. By drawing intersecting arcs from each shot point, the radii being proportional to the projection of the seismic path on to a horizontal plane, the approximate position of the detector can be arrived at. If further shots are fired about a point vertically above this on the surface, a closer approximation can be made. The method does not commend itself in practice, as in addition to the use of an exceedingly delicate instrument there is the disadvantage of using a quantity of explosive. Where gas risks are high this will preclude its use. Further, a value for the average vertical velocity is liable to considerable error in highly folded structures with beds of varying density.

Correction.

While the cure for crooked hole is yet to be found, wells may be deflected by means of a whipstock to follow any desired direction. The method followed by mining engineers in coping with diamond bore holes which may need deflection is worth considering in relation to oil field problems.[9] The hole is first plugged about 15–20 ft. below the point at which deflection is required, and a drive wedge is tamped in. The top surface of this is inclined at about 30° with the centre line of the wedge. An impression block is now run with a Maas compass, and the orientation of the inclined surface is obtained. The pilot wedge is next screwed to the deflecting wedge so that the latter will offset the bit in the desired direction, and the two wedges are run down into the final position.

A second method is to drill ahead slowly with bits considerably smaller than before. If care is taken not to force the bit, it will hang towards the footwall, and when the hole is subsequently reamed out with a full sized bit, the hole will tend towards the vertical. Diamond-point bits will be preferable in this case to fish-tail bits, as they will centre themselves better in the pilot hole.

These methods only influence the future course of the hole. The only means of straightening up holes already drilled is by prolonged reaming.

Conclusion.

With increasing insistence being placed on the necessity for straighter drilling more attention is being paid to automatic feeds, more efficient types of bits and weight indicators. Competitive drilling on adjoining leases, resulting in record footage, is counteracted by co-operation between contractors and employers' bonus for straight holes, and bringing home to the operators that quality rather than quantity is desired.

In the present-day oilfield there is a strong demand for an efficient and simple inclinometer which will satisfy the needs of geologist and driller. When the information obtained by means of such an instrument is applied to existing records, it is possible that interesting developments may occur in abandoned areas.

In writing the above paper the author has to acknowledge the valuable assistance afforded him by Professors Illing and Milner, of the Royal School of Mines, and Messrs. Harcus and Lake, of the Burmah Oil Company.

So much fresh information is forthcoming from the technical press that it has been difficult to arrive at definite conclusions. It is hoped that the paper will afford opportunities for discussion on the problem among petroleum technologists, whose experience extends to fields under British control. The problem has been investigated with great thoroughness by American operators, and it should prove interesting to compare these results with those obtained in various parts of the globe.

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DISCUSSION.

The President said that any points raised in the discussion would be forwarded to the Author, who was abroad, but Capt. Comins would no doubt desire to comment on the paper.

Mr. A. Beeby Thompson said the subject of the paper was of very great importance to oilfield operators to-day; it dealt with a comparatively new line of study about which very little was known; indeed, only recently had instruments been produced which would give reliable records in deep wells. When Mr. Anderson published his first surveys of Californian wells several years ago the results were generally discredited, until he repeated his tests time after time and got practically the same readings each time. Mr. Anderson, the pioneer of oil well surveys, visited England a year or two ago and he, the speaker, had had the pleasure and privilege of seeing many of his surveyed sections of wells; it astounded one to see the way in which a drill would corkscrew its passage, deviating first in one direction and then in another and in some cases actually ending at a point vertically below the mouth of the bore. Even experienced drillers questioned whether it was possible for such deviations as recorded to pass unrecognised. Simple methods had been adopted to check the verticality of shallow wells in which, as a rule, the deviation was not great, but until the last few years no operator imagined that boreholes could drift unnoticed 700 to 1000 ft. from the vertical at depths of 5000 to 7000 ft. Unless some mechanical difficulty caused one to suspect a departure from verticality, wells are assumed to be reasonably true. They knew that in ordinary mining when exploring with the diamond core-drill it was quite a common occurrence for the drill to run considerably out of the direction in which it was started; and the tendency of rotary drills to deflection on meeting obstructions or changes of strata was never disputed. No one suspected, however, that drills would operate normally at inclinations which have been measured, yet when one considered that a 4 in. drill-pipe suspended in a 5000–6000 ft. hole was really equivalent to a light cord, it was amazing that wells did not deviate more frequently than they did.

The measurement of deviation was a subject on which very few could speak authentically because little field work had been done in this direction outside America. In many countries such tests had been viewed with almost consternation because it was quite certain that in many cases deep boundary wells on small properties would have crossed the border and be drawing oil from neighbouring properties. Such knowledge was likely to lead to costly and prolonged litigation. Such a state of affairs was probable in Burma

where drilling in one great field is conducted on plots only 60 ft. diameter; and in Rumania where single properties of an acre or two in extent were operated, and it was the custom to drill as near the boundary as regulations allowed. The correct measurement of the degree and direction of deviation was one of extreme difficulty and instruments in use are complicated, often controlled by patents and can only be worked by an expert operator. Various methods had been suggested to reduce the tendency to deviation, but it was very difficult to say in what direction lays a remedy. The so-called stabilisers which were now being used on drill-pipe seemed to offer a possibility of some improvement. He had been at first inclined to question the wisdom of using these rubber collars on a rotating pipe in an open hole, but they were coming into general use and proving of some benefit. The steadying of the drill tends to check movements set up by slight distortions of the drill-pipe due partly to excessive weight on the bit and must assist in securing the verticality of wells. Straight drilling of deep wells depended a great deal upon the personal equation. There was no doubt that verticality of wells was very closely connected with the adjustment of feed of the drill. Personally he had always attached great value to the use of a long guide piece above the bit such as was mentioned by the author. The tendency to deflection could be reduced by using a drill-pipe nearly equal in size to the diameter of the bit, but such was impracticable when drilling at depths of 6000 or 9000 ft. on account of excessive weight. There would appear to be a limit to the depth at which a fishtail or other form of bit could be controlled by a light drill-pipe representing little more than a cord in wells a mile or two miles deep. He felt sure they would eventually develop means of transmitting the power to some working mechanism near the bit, thus avoiding the necessity of transmitting the rotary motion through the medium of a shaft from the surface.

Mr. B. J. Ellis said that he disagreed with Mr. Beeby Thompson's statement that nothing much had been done in this matter outside the United States of America. Though he could not claim to be the first man to have taken inclinometer readings in an oil well, he believed that Mr. Evans, who was present, and himself were among the first to put them to practical use. In 1924, about a year before the subject was thought of at all in the U.S.A., during the drilling of a well in Assam, a core was taken showing a vertical dip. Mr. Evans insisted that the dip could not be vertical and that the hole must be crooked to the extent of some 23°. He, the speaker, had denied the possibility of this, as the drilling was proceeding quite satisfactory, and there were no extraordinary signs of wear on the drill-pipe or difficulty in making the hole. It was very

desirable to find out which of them was right, and after a little thought and calculation, the open-ended inclinometer described by the author was made up in the workshop and run into the well. A perfectly good reading was obtained showing that the geologist was right and he, the speaker, was wrong. Very shortly before this mud fluid was lost in another drilling well and a complaint was received from the production department that one of their small producers was full of mud. A fissure was suspected, and arrangements were made to set a string of casing to isolate the one well from the other. This was done, and drilling was continued; but as soon as the inclinometer was available, tests were made which showed that the drilling well had gone through, or close to, the bottom of the producing well. After these experiences inclinometers were brought into general use on drilling wells in Assam.

Since that time he had naturally taken a more than ordinary interest in the practice of well surveying, and had followed very closely the efforts which continued to be made to drill vertical holes, but he thought it rather wrong to suggest that the old timer's maxim was "Oil at any cost, no matter what shape the well." Prior to 1924 in Assam, or 1925 in the U.S.A., drillers firmly believed that their holes were vertical if there was no difficulty in running the drill-pipe or casing, and there were no means available on oil fields for proving or disproving the correctness of their belief. It was true that when means became available, the idea that holes were anything but vertical was pooh-poohed by responsible oil men. He had asked the opinion of the head technical man of one of the largest oil companies in the U.S.A. in the early part of 1925, only to be told that oil wells were not crooked, and that the taking of inclinometer readings was waste of time and money. He noticed, however, that very shortly afterwards acid bottle inclinometers were being run in a number of holes by that same company, and that Mr. Anderson's instrument, which had just then been perfected, was being used by them.

Inclinometers might be divided roughly into two classes: first, those for use while the well was being drilled, and, second, those for making a complete survey of the well when completed or before setting strings of casing.

In the first class, the latest development was in the form of a go-devil acid bottle which is dropped down the drill-pipe and centred itself in a splined substitute just above the drill collar. A reading could be obtained at the cost of only half an hour in time compared with the several hours occupied in running the earlier types of inclinometer on the drill-stem, or a day or more with the Anderson type. A slight correction had to be made to the reading owing to the drill-pipe not being guided in the hole, but if the bit

was always lifted off the bottom the error would always be in one direction and could be fairly easily calculated and allowed for. In the second class, the latest instrument was one recently developed by the Sperry Gyroscope Company in collaboration with the Sun Oil Company in the Mid-Continent Field, U.S.A. This consisted of a photographic apparatus, a bubble level and a gyroscopic compass, the camera taking frequent records both of the bubble level, and of a north and south pointer actuated by the gyroscopic compass, as the drill-stem travelled down the hole.

Both instruments showed a considerable advance on anything previously available, and it was unfortunate that the manufacturers of the last-mentioned were not prepared to sell their instruments for use out of the U.S.A. The go-devil type was, however, easily made up in any field's workshop.

The drilling of vertical holes was a matter of very great difficulty, and the information given by the author would no doubt be of considerable value to those at present endeavouring to carry out this difficult task.

In his, the speaker's, view, the cutting powers of the bit, the concentration of weight at the bottom of the drill-stem, and correct feeding of the drill-pipe were the most important features. A bit with infinite cutting powers would not tend to deviate from the vertical however fast it was fed, and in practice the greater the cutting power the less would be the deviation. Holes drilled with a diamond bit were not so terribly crooked as their 2 in. drill-stems would lead one to expect, and the use of diamond substitutes on all forms of drilling and coring bits was undoubtedly well worth while in spite of their high cost. By concentrating the weight at the bottom of the drilling string, by using large diameter long drill-collars, it was possible to bring the point of no tension stress in the drill-pipe to the junction between it and the drill-collar. The section of the drill-collar could be made such that it would easily support its own weight as a column, and the only amount by which a hole could then deviate was the small angle at which the long drill-stem could lie over in the hole being drilled. In Burma the combination of 10-in. drill-collars 20 ft. long, and a few joints of 10-in. casing used just above, had given experimentally the best results, and a quantity of 10-in. drill-pipe with tool joints was now being sent out to enable drilling in this way to be extended. The size of drill-pipe above the bottom stand was not of much importance provided it would stand the torsional and tensional stresses. Experience in Burma had been that reamers 20 ft. or so above the bit tended to increase deviation rather than to decrease it.

In his description of various methods of feeding the drill-pipe, the author did not mention hydraulic control. The differential

arrangements which he described were designed to maintain a constant pressure on the bit at one setting of the control. The setting had to be varied for each type of stratum and for different types of bits, but owing to the automatic action, the correct setting was not an easy matter. With hydraulic control, on the other hand, the driller had an exact knowledge of the weight on his bit and could see immediately the effect of feeding at different rates. There was nothing automatic about the arrangements, and the driller had the complete control which he needed.

In conclusion, he desired to stress the comparatively greater importance of drilling a hole vertically than of measuring the hole after it had been drilled crooked. It was hoped, therefore, that some one of the members who was struggling with this problem on the field would give them the benefit of his experience in a further paper at no distant date.

Professor V. C. Illing said that he agreed with Mr. Ellis's statement, that it was of greater importance to drill a hole vertically than to measure the hole after it had been drilled crooked. As a geologist the problem appealed to him from the geological aspect. In measuring the angle of inclination of cores, one was always faced with the problem whether the angle of dip met in the core had really to be added to the angle of inclination of the hole or subtracted. In other words, the actual phenomena of dip that one got from a core might become exceedingly misleading, unless one knew something of the relationship of the core at that point to the strata. Until the importance of these deflections were appreciated, a lot of misleading data must have crept into their records in the past which it must have been exceedingly difficult for the geologist to fit in with any possible type of structure. It was not merely that the evidence which they got was wrongly placed, but it was wrongly interpreted. As to the legal problem, when it was proved that undertakings were taking oil from their neighbours' land, he presumed they would have to follow the old law, analogous to the game law, that the oil belongs to the person who gets it. The problem was one which would either provide revenue for the lawyers or would have to be settled by the drilling fraternity drilling straight holes instead of crooked ones.

Mr. N. Matheson said that most of the systems of surveying which had been mentioned by the author, and indeed most of the systems in present-day use relied on the orientation of drill-pipe for readings of azimuth. It had always appeared to him that there must be a certain amount of twist in the pipe which was actually run for the surveying. When he first read this paper he decided to investigate this question of twist further. In view of the difficulties of calculation, he had made up a small model of a well

something on the lines of Olinda No. 96, with a $\frac{1}{8}$-in. copper pipe to represent an 18-in. hole. He had approached as near as he could to 1000 ft. of hole on this scale. He had gradually inserted a piece of $\frac{1}{16}$-in. diameter steel on which was etched a straight line. He had not been surprised to find that the 1000 ft. to scale had given him a twist in the steel wire of something like 26° in an anti-clockwise direction. Most of the surveys which were run to a depth of 6000 ft. or so, and gave deviations of 500 ft. from the true vertical, might therefore be in many cases 200 or 300 ft. either to right or left of the surveyed point. One could not rely on the drill-pipe being put down a hole remaining perfectly rigid. A twist of 1° per 100 ft., which was 60° in 6000 ft., only required a torque of something like 10,000 in. pounds, which one man could easily put on the pipe by exerting his force at the end of an ordinary 6-in. pipe tong. One could therefore appreciate how easy it was for that pipe to twist in going down an irregular hole with shelves, cavings and so on. It seemed to him that this method of surveying holes by a succeeding series of spot readings for depth inclination and azimuth must, as the reading goes on down the hole, produce an increasing error. He thought the solution from the surveying point of view would be in the form of some system which would give the true bottom hole reading direct. One reason why the methods of surveying mentioned by the author were not resorted to so much was that they involved shutting down the hole for 24 hours or so to run the survey, apart from the question of possible litigation to which reference had been made. It had occurred to him some months ago that the future would bring forth some method of surveying by means of directional wireless. He had discussed this with some of the experts who were responsible for the present direction of aircraft by means of beam stations. It appeared to involve lowering some form of transmission apparatus down the hole, using a fairly long wave length, and a further study of the question of the refractive index of the various strata through which the wave was likely to pass. Short waves appeared to be unstable, and waves in the order of 20,000 to 30,000 metres would probably be required. He understood from recent experiments of transmission through the ground that the ultimate error in a hole 4000 ft. deep would probably not be more than 3°. He suggested this as a possible future method of surveying oil wells. The difficulty, of course, was to get the power to the bottom of the hole ; something like 30 kw. would be necessary, and, of course, one would not be allowed to put a wire down the hole inasmuch as it would form an aerial. He thought that this objection could be overcome by using a compressed air chamber to drive a generator for a short time. It seemed to him that the discussion had been mostly directed

towards cure, but it was the prevention of crooked holes that was necessary. He agreed with previous speakers that the ultimate system of drilling must be something which did not utilise the transmission of torque in a long string of pipe which was bound to cause crooked holes. He had recently discussed the subject of crooked holes with Alexander Anderson in America. The results of surveys made by him showed almost unbelievable deviations. Until Anderson put surveying on an everyday basis operators usually assumed all holes were reasonably true and they did not realise that drill-pipe in a hole does not revolve on its centre but rather like a helix, much as a corkscrew revolves.

He thought that the cure of crooked holes lay in the application of the power at the bottom of the hole.

Capt. D. Comins said that Mr. Matheson's views with regard to the possibility of error due to torque in surveying methods which relied on sighting down the drill-pipe were generally held in the Mid-Continent, where he had found considerable prejudice on this account against Anderson's method of survey, but which, at the time he was out there, was the only method in general use in California for measuring horizontal deflection. Upon this objection being put to Mr. Anderson, he had replied that the proof of the pudding was in the eating, that duplicate surveys by his method were practically identical (within a 40 ft. radius at the bottom of a 5000 ft. well), and that he had measured intersecting holes accurately, as was proved by the evidence from the wells. He should mention that Mr. Rees was misinformed in classifying the Anderson as a magnetic method. No magnets were used in the apparatus which had been examined by him.

He was sure that any geologist who had seen an underground contour map of the Seminole field before and after correction for crooked holes would appreciate the importance of well surveying. Before correction the map was studded with small domes, whereas after correction the structure was shown to be comparatively simple. He regretted that the author had not dealt in greater detail with the methods of surveying which had been evolved during the last year. A year ago in America Mr. Anderson's method was the only modern method for measuring all the way down with one reading and for measuring the horizontal as well as the vertical deflection. During the last year several new methods had been evolved in the States for doing the survey in one run. For operators outside the U.S.A. the difficulty in selecting a modern method of surveying was that when one saw an article about them in trade journals and made enquiries, one received a manufacturer's pamphlet in which the technical description was very meagre (for fear of patent infringements) and, although the claims were very substantial,

authoritative data or references were never supplied to permit one to check up as to whether these instruments had actually been tried out successfully by operating concerns.

Had anyone present had any experience of the following instruments ?

(a) For measuring vertical deviation in one run : the Syfo Gyroscopic instrument made by the Sperry Sun Well Surveying Company (referred to by Mr. Ellis) ; or the Driftmeter (an electrical device for recording at surface movements in a plumb-bob at depth).

(b) For measuring both horizontal and vertical deviations in one run : the Surwell Gyroscopic instrument (also made by the Sperry Sun Well Surveying Co.) ; or the Rieber (an instrument in which vertical error was measured by a plumb-bob and horizontal error by a magnet, records being punched on a series of automatically fed aluminium discs. This instrument, which is run in a length of non-magnetic pipe, was only claimed to be successful in open hole.)

He hoped also that any members who might have experience or information regarding the success of any of the instruments mentioned would send in their views in writing.

Mr. P. Evans mentioned that the results of drilling in several parts of Assam confirm the author's remark that there is a tendency to up-dip deviation when drilling through strata with low dips and down-dip deviation when drilling in steeply dipping strata, although it is suspected that small deviations are often independent of structural control.

It is impossible to assess the value of results obtained with various straight-hole devices without some knowledge of the nature and dip of the strata drilled through, yet these particulars are usually omitted from descriptions given in technical periodicals. In theory there is much to be said for the use of pilot bits for large holes in steeply dipping strata. These were tried in Assam but owing largely to difficulties in dressing pilot bits a return was made to the fishtail bit, with rock-bits for hard beds and, to some extent, for reaming. To be really satisfactory in steep dips the pilot bits should have a long " lead " and this would necessitate redesigning the bits to bring the mud-flush near the pilot cutting edge.

Assam experience has been that it is much easier to drill straight in the first instance than to rectify a hole that has gone crooked. Usually if the deviation is not allowed to exceed about 3° or 4° the hole can be straightened without difficulty, but if a deviation of say twice this amount is allowed to persist over a fairly large range

it is very seldom possible to bring about any appreciable reduction. One of the deepest wells in India was drilled in very steep dips in alternating strata and very gradually went off the straight until at cementation the hole was approaching the permissible limit of deviation. After cementation the deviation was reduced by coring and slow drilling until the well was sufficiently nearly vertical; thereafter drilling went ahead much faster and at 4400 ft. the deviation was 2°.

Wells drilled in Assam do not support the suggestion that there is any connection between big slush-pumps and crooked holes, nor do they support the recommendations usually given to take very great precautions in keeping the Kelly vertical when starting up.

In view of the importance of drilling straight the first time, and avoiding prolonged straightening operations, the "go-devil" acid inclinometer has been found most convenient and readings may be taken as often as every 50 ft. In addition, it is desirable to survey each hole before setting the water-string, but no satisfactory instrument has yet been obtained. Orientation methods have so far only been successful at shallow depths, although elsewhere in India these methods have given consistent results down to 3000 ft.; there is, however, likely to be a persistent error which repetition will fail to detect. Cores have occasionally been taken to find out whether a pronounced deviation is up or down dip.

Mr. C. Dabell said that hydraulic feed would, he thought, eventually be found the best for rotary drills. He agreed with former speakers that attempts should be made to prevent crookedness rather than to measure deviation afterwards. One must therefore first enquire as to the causes of deviation. The main cause was steeply dipping and hard formation. Another was large sized pumps when used in a sandy laminated formation. Also, it was obvious that to use a 4½-in. drill-stem in a 12-in. or 14-in. hole was asking for trouble. Another cause of a crooked hole was the use of core barrels in a hole already slightly deflected. It was very obvious that if one went into a 12-in. or 14-in. diameter hole at say 2000 ft. with a 3-in. core barrel of 8-in. outside diameter, the chances were that the barrel would go to the outside edge of the existing hole, the rock or fishtail bit would, by following the line of least resistance, follow where the core barrel had been, thus throwing the bit to one side of the drilled hole. Another cause was undoubtedly the weight used or carried on the rotary bit; if too much weight was carried the result was that with a steeply dipping formation the bit would go down, while with a gently dipping formation it would tend to go up. Manufacturers of rock bits had recently

advised that their engineering department did not recommend a greater weight than 2000 lbs. per inch diameter of the rock bit.

He wished to congratulate the author on the production of a paper which so lent itself to discussion and regretted that time did not permit members to go more closely into detail of the subject.

Dr. J. A. L. Henderson said he presumed that Mr. Beeby Thompson when he said this was a "new thing" was referring only to oil well practice, because borehole surveying had long been routine work in mining. Twenty to twenty-five years ago the practice of surveying boreholes was becoming common and very efficient surveying instruments, giving inclination and orientation, were employed for boreholes as deep as 6656 ft. These instruments were now being adapted by Anderson and others to the larger scale borings for oil. What was surprising was that these had not been introduced into oil well practice long ago. Some American technologists had told him that the trouble, delay and expense involved in endeavouring to drill absolutely vertical holes were not justified because no harm was done by a small amount of deviation; but with the increasingly deeper drilling which was now taking place serious drilling and production troubles arose—apart from geological and legal considerations—which made it imperative to discover means of avoiding and correcting deviation. Very great interest was therefore being taken now in this subject. With regard to the possibility of drilling into one's neighbour's property owing to deviation, he believed that the law in the United States was that he who captured and reduced to possession the vagrant mineral, oil, was its owner; he did not know whether it mattered whence the oil was obtained so long as one started drilling within one's own land.

The only way to avoid deviation was to start straight; maintenance of verticality could only be ensured by constant surveying of boreholes during the course of drilling; by that means, and careful drilling, most boreholes should be kept within a reasonable limit of deviation even at depths of 5000 or 6000 ft.

The author had done a timely service to British oil technologists in presenting this general review of an increasingly important problem, and by placing at their disposal the results of his own observation and practical experience in the prevention and correction of borehole deviation.

The President said that any further contributions to the discussion would be sent in in writing.

On the motion of the **President** votes of thanks were accorded to the author and to Capt. D. Comins for reading the paper.

Mr. D. P. Rees, in reply, wrote :—

Several of the speakers refer to the Anderson Inclinometer, and to the difficulty of proving the reliability of the azimuth determinations. Although Mr. Anderson has produced remarkable figures backing up actual known data from well logs and duplicate surveys, there appears to be little doubt that twisting of the stem, such as can be observed when going in the hole where rifling or other irregularities exist, is not transmitted to the surface altogether. A deflection of 10° in azimuth could be absorbed in a string of 5000 ft. of 4-in. drill-pipe in internal stresses, particularly where there was considerable wall friction as in the case of an inclined hole. Again where drill-pipe is pierced and rolled in the shops and made up with the couplings on the same end of the joints it is probable that internal stresses already exist to a certain extent and might effect the orientation of the string as a whole. This is however a matter for the decision of a metallurgist.

Mr. Beeby Thompson mentions the employment of drill-pipe practically the size of the hole. Although this would appear to be the theoretical solution of the whipping action of the pipe, limitations have to be imposed, as he mentions, by weight considerations, quite apart from increased circulation troubles and fishing difficulties. The same effect can be gained, as Mr. Ellis remarks, by the employment of extra heavy drill-collars with a comparatively small drilling string, fitted with rubber protectors and stabilisers, the weight being applied where most effective just above the bit.

As mentioned by Mr. Ellis, the cutting power of the bit constitutes one of the most important factors in straight hole drilling. The bit footage is increased by the application of hard facings or the design of bits to cut an annular hole and destroy the unsupported core as formed.

The author has had no experience of hydraulic feed, but it would appear that more complete control would be exercised over the bit loading with a minimum of personal exertion. Providing other factors, such as rotational speed, correct dressing and selection of bits, etc., are not neglected, hydraulic control would seem to have decided advantages over hand feed or differential control.

Mr. N. Matheson's experiment and his proposed adaption of medium long wave directional wireless are of considerable interest, but in the latter case the same difficulty appears as with seismographic determinations—*i.e.*, a value for the average vertical velocity of the waves, particularly in areas of complex folding.

Very little has been said about the different proprietary inclinometers in detail, by reason of the secrecy which naturally surrounds them and the difficulty of their application to the industry as a

whole. An instrument had been devised by the author employing a gyroscope in a housing equipped with an indicator, the latter marking a record strip at predetermined intervals. This, however, has not been proceeded with from lack of opportunity. The mechanical difficulties, too, of having a gyroscopic instrument sufficiently small to run in pipe of small diameters are very great.

With reference to Mr. Evans's statement regarding the necessity for initial verticality, perhaps a little too much stress was laid, but it is a common sight for the swivel to be rotating eccentrically and the lines swinging from side to side of the derrick when a well is spudding in. This naturally leads to large diameter hole, and the pull of the circulating hose when the kelly is well up being very considerable will tend to force the bit to the side opposite to the hose, as the rigidity of the drill-stem is then an important factor. Correct lining up of the outfit is naturally of primary importance.

The difficulty of bringing back to the vertical wells of over 5° deflection is due possibly to inability to start a ledge where the increase in deflection is very gradual. In such a case side wall hydraulicing with a special head fitted with nozzles might be employed. If this is slowly rotated and gradually raised a cave should be started on the footwall side, which by judicious washing can be worked into a shoulder and give a good start for subsequent reaming.

Mr. Evans emphasises one of the most important features from the surveying view point, the correct isolation depth. If this is incorrect the isolation string may be valueless as a water shut off, and if oriented drill-pipe readings are proved to be misleading only a general inference of dip from neighbouring wells and core evidence will be possible with resulting increased possibilities of error.

Mr. Dabell ascribes one cause of crooked hole to the hydraulicing action of large pumps. If, however, the flow is reduced on entering a hard formation from a relatively soft bed, this tendency to enlarge the hole is reduced, and the increased flow in homogeneous strata will tend to keep the hole clean and, as has been recently suggested, the increased pressure may tend to stiffen the drilling string and reduce the bit pressure.

The writer, however, differs as regards his statement regarding the chances of going off still further with core heads or bits of reduced diameter. Experiments in Burma have shown that smaller bits tend to keep to the footwall side of an inclined hole, and that if run alternately with bits of full diameter the tendency will be for the hole to regain the vertical. Observations on a number of wells showed a reduction of inclination of 1° per 100 ft. When

drilling with 15½ in. bits and upwards 12¼ in. bits are run, with 9¾ in. bits, 6 in. would be usual, though the effect of straightening is not so great as in the larger hole. Care has naturally to be taken in starting the pilot hole.

As Dr. Henderson remarks, it is astonishing that more use has not been made of mining experience in dealing with the problem of surveying holes.

The writer concludes by thanking Capt. P. D. Comins for being so good as to read the paper.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

TRINIDAD BRANCH.

THE THIRTEENTH ORDINARY MEETING of the Trinidad Branch of the Institution of Petroleum Technologists was held at the Club House of Messrs. Apex (Trinidad) Oilfields, Ltd., Fyzabad, Trinidad, on Wednesday, October 30th, 1929, and the Chair was taken by Mr. A. Frank Dabell.

The following paper was read :—

Measurement and Sampling of Mineral Oil.

By J. S. PARKER, M.A., B.Sc. (Member).

It is intended to deal with the subject generally and to note certain points which have arisen during a certain experience of the oil industry, but it is not proposed to make recommendations with regard to methods.

LARGE STORAGE TANKS.

Calibration.—Large storage tanks are strapped—*i.e.*, the external circumference of the tank rings is measured by means of a steel measuring tape.

Riveted tanks are built on two principles : (1) Bottom edge of plate inside, top edge outside, and (2) rings alternating outside and inside up the tank. In the case of (1) measurements are taken at the dead centre of the plates comprising the ring, and in (2) at any part of the plates. In both cases strapping should be parallel to the horizontal seam and clear of rivet heads as far as possible.

Top and bottom rings are always strapped, but it is not general to measure more than the first, second, third and top rings, the figures for any other rings being interpolated.

When the tank strapping is completed, the manhole on the tank side and any deadwood such as blocks, swing-pipes, etc., inside are measured. Allowance is made for vertical seams and any rivet heads and the external diameter of each ring calculated, the internal diameter being obtained by subtracting twice the plate thickness. The average internal diameter is then calculated and the total capacity of the tank determined, the manhole volume added and the deadwood volume subtracted. The final result is then averaged to give unit volume per unit of depth. In Trinidad this is Imperial Gallons per inch.

Accuracy.—Bell (*American Petroleum Refining*) gives the general U.S.A. accuracy limit as 0·04 of 1 per cent. of tank volume at full capacity. This is approximately equivalent to the volume of $\frac{1}{2}$ in. of tank depth. For general transactions, where sales or purchases are not concerned, he quotes the general U.S.A. accuracy limit as 0·1 of 1 per cent.

Observations.—Tank strapping should be carried out carefully and accurately, but it must be recognised that there are limits to the accuracy possible, and it is interesting to see how far the generally adopted methods fall short of accuracy.

It is quite within the bounds of possibility that the tape used may not be accurate. The use of circle formulæ assumes that the tank section is a perfect circle, but how often is this checked and how often is it ascertained that the tank sides are perpendicular to the liquid level? Does anyone ever worry about flats on tank plates?

An average figure is generally calculated for the tank, even though the manhole and deadwood are at the bottom. The difference is so small that it does not justify drawing up of inch-by-inch tables. Purchases are also taken to a bottom dip of 3 ft., which eliminates manhole, deadwood and water and sediment difficulties.

The tank bottom is assumed to be level, but it is practically certain that it is not. Where tank tables are based on an average figure per unit depth it is more accurate to omit any allowance for the contour of the tank bottom.

If the position of the bottom angle of the tank when full and when empty is noted, it will be apparent that a certain amount of movement has taken place. Some companies allow for this on large tanks. According to their formula the additive correction for a full 55,000 bbl. tank is about 25 bbl.

Small Storage Tanks.

Calibration.—These tanks are generally calibrated by the strapping method. Other methods adopted are: (1) To weigh the tank full and empty; and (2) to fill the tank from a container which can be weighed full and empty or which can be very accurately measured.

Horizontal cylindrical tanks are more troublesome as they must have their volume calculated for each unit of depth—*i.e.*, a figure cannot be averaged over the tank. For a straight-ended horizontal tank a rapid and accurate method is to draw the average strapping diameter to scale on squared paper, using a square or a multiple of a square to represent unit depth. By totalling the squares and

part of squares bounded by each unit of depth the square area is obtained, and from this the volume can be readily calculated.

The dished-end horizontal tank is the most difficult to calibrate. The sectioning on squared paper method may be adopted for calibrating the actual cylinder. The dished end is never a perfect spherical segment. To get at this the use of triple integration is necessary, which is probably beyond the majority of oilfield staffs. In practice the dished end is assumed to be a spherical segment, and its total volume is worked out according to spherical segment formula. This total volume is then proportioned to units of depth according to the square area bounded by these units of depth in the tank cylinder section.

Accuracy.—Small tanks are relatively easy to measure, and it would appear that the actual measurements are more accurate than those of the large tanks, but it is a doubtful point whether they even have similar calibration accuracy to that of the large tanks. Where they have the advantage is that they have greater dip accuracy—*i.e.*, 1 inch on a small tank is only equal to a fraction of the capacity corresponding to 1 inch on a large tank.

Barge Tanks.

Calibration.—These can only be accurately calibrated by filling from an accurately calibrated tank. Calibration data are generally supplied by the makers, but check is advisable.

Observations.—Sound pipes. Dipping tanks. Tables.

Gauging.—This is generally carried out by means of a steel measuring tape to the end of which a heavy plumb-bob is attached. Two methods are in use :—

(1) Ullage. A definite measure on the tape which is greater than the distance from the top of the tank to the oil level is held at a definite point on the manhole or sounding pipe rim and the tape is let down into the tank. The tape is withdrawn and shows the top of the oil mark. This reading subtracted from the measure where the tape was held is the ullage.

(2) Dip. In taking the dip the tape is let down into the tank until the sharpened point of the plumb-bob just touches the bottom. The tape is withdrawn and the top of the oil mark is the dip.

Observations.—Of the two methods, ullage is the more accurate if properly carried out. It is necessary that the roof from which the ullage is taken is rigid and that the ullage is taken from a definite spot on the manhole or sound pipe.

The dip method is more generally adopted and its accuracy is dependent on the condition of the tank bottom. It is accurate provided it is carried out over a limited part of the tank bottom, preferably through a narrow sound pipe, and that a sufficiently heavy plumb-bob is used. Four dips at diagonal points should be taken on large tanks.

A plumb-bob of the following dimensions has given satisfaction for general gauging: Cylindrical, $\frac{7}{8}$ in. diameter, 7 in. long, with last 1 in. turned down to a cone point.

Water.

Free Water.—Water which settles out in a tank should be bled off and the result checked by water-finding apparatus.

As far as vertical cylindrical tanks are concerned, the water dip can be subtracted from the total dip before calculating results. In the case of horizontal cylindrical tanks the water dip and the total dip must both be calculated before one can be subtracted from the other.

Suspended Water.—This applies chiefly to crude oil. Samples for water estimation should be analysed as soon as possible after they are drawn. It is extremely difficult to get any water which may settle out on standing to emulsify back into the sample.

Temperature.

Tank temperatures are checked by means of a thermometer whose bulb is immersed in a tin cup. A great deal depends on accurate temperatures and it is surprising how little attention is paid to checking the accuracy of thermometers.

The taking of an accurate average temperature of the contents of a tank is a problem which is probably beyond solution, especially under extreme local sun conditions. The temperature curve must vary from top to bottom and across the tank from the sun side. Yet the industry has got no further than immersing a thermometer for a certain period in the oil and drawing it up with its bulb in a sample of the oil. There is room for improvement in the apparatus along the lines of the maximum-minimum thermometer.

A temperature out by one or two degrees soon brings one outside the tank accuracy limits.

Temperature Correction.—The standard temperature to which all volume and gravity measurements are converted is 60° F. Conversion to this temperature should be done in as few stages as possible. Two temperature correction tables are in general use: (1) Volume correction, and (2) Specific Gravity correction.

The temperature correction figure is not the same for both, but one may be obtained from the other. For example, the increase in unit volume of a crude oil from 60° F. to 61° F. is say 0·0004, and the specific gravity of this crude at 61° F. is say 0·900. Then the specific gravity correction is 0·0004 × 0·900, or 0·00036.

As there is sometimes doubt as to the correct method of using the volume correction figure, it is advisable to work it out from first principles :—

Let V = Volume of oil at 60° F.
V_t = Volume of oil at temperature "t."
X_t = Volume correction for temperature "t."
Then $V_t = V + X_tV = V(1+X_t)$.

$$V = \frac{V_t}{1 + X_t}$$

Similarly, for specific gravity :—
Let G = Gravity at 60° F.
G_t = Gravity at temperature "t."
Y_t = Gravity correction for temperature "t."

$$\text{Then } GV = G_tV_t \frac{GV_t}{1 + Y_t} = G_tV_t.$$
$$G = G_t(1 + Y_t).$$

It must be noticed that temperature correction tables generally give worked out factors which enable one to arrive at the result by straight multiplication.

Sampling.

Samples are taken from the top, middle and the agreed bottom of the oil in the tank, and are either dealt with singly, or are averaged and dealt with as a whole. Where crudes vary over a wide range and are dealt with in comparatively small lots, it is doubtful whether the system is as accurate as might be. Local crudes stratify readily and it might be possible to average a top, middle and bottom sample which was not representative of the oil in the tank. There would appear to be scope for a form of "thief" which would take a core from top to bottom of the oil.

Units of Measurement.

The official measures in Trinidad are British. All fields have at some time been influenced by American methods, and American measures have been, and are still being, used. The measures used in Trinidad may be summarised as follows :—

Fields.—Linear, Feet and Inches; Cubic, Imperial Gallons, Imperial Barrels; Weight, Long Tons.

Refineries.—Linear; Feet and Inches; Cubic, Imperial Gallons, Imperial Barrels, United States Gallons, United States Barrels; Weight, Long and Short Tons.

Returns have to be made to the Government in the official measure, deliveries to customers in their measures, and a certain amount of latitude has to be allowed to the records department. Volumes and weights are dealt with at one and the same time, and there is little doubt that the ideal system is the Metric.

Metric System. Linear and Square Measure.—Dips would be recorded in centimetres to one place of decimals, and square measure would be in square centimetres. A visual check is all that is necessary for the metric system, whereas with feet and inches one has to work out the figures to check the final result.

Cubic Measure.—The unit of cubic measure would be the litre and results would be recorded to one place of decimals. The centimetre cubed becomes the cubic centimetre, and there are approximately 1000 c.c. in a litre.

Weight.—The units of weight would be the kilogram and the metric ton of 1000 kilograms. The metric ton is about 2205 lb.

It is not proposed to deal further with the metric system as its advantages are well known to all. It is the ideal system for the oil industry.

In conclusion it may be said that there is a tendency for the Industry to be careless where accuracy is necessary. The metric system has been dealt with as with greater ease of calculation comes a greater percentage of accurate results.

DISCUSSION.

Mr. O. F. Nothnagel said that the Author had referred to Imperial and American Gallons, and Imperial and American Barrels. He suggested that, while a difference existed in the measure of the gallons, such difference should not extend to the unit "barrel." The content of a barrel was 42 American Gallons, equivalent to approximately 35 Imperial Gallons, each resulting in the identical unit—one barrel.

Mr. P. H. B. Trasler said that assuming that one can dip accurately to $\frac{1}{8}$ in. through one manhole then, if dips are taken from four holes, the average dip is accurate to $\frac{1}{16}$ in.

If one is dealing with a mixture of different crudes in one tank, the method of "all level samples" is a possibility. In this method it is arranged that the sample is taken in such a way that the

thief is just full by the time that the top is reached. This, in theory, would give a true sample, but it would probably be a rather difficult method for the majority of gaugers.

As regards taking a dip from a standpipe and not from a manhole, it is quite feasible that the middle of a bulge might come underneath the standpipe.

Mr. A. J. Ruthven-Murray said that it would be interesting to know whether there is any practical difference in the volumetric capacity of a large tank when subjected to varying degrees of temperature such as changes which obtain between the hot and cold season and between a tropical day and night. It seems probable that there would be considerable difference in volume between temperature ranges of 65° F. to 130° F.

Colonel Hickling said that there was a third kind of tank used in Trinidad, in which the sides tapered in by the thickness of the plates, i.e., each ring telescoped within the one below it.

Another point was that, in order to obtain greater accuracy in the dip to balance temperature differences, it should be specified that the four dip holes should be spaced equally at 90 degrees, and on a circle that would give an equal capacity of the tank inside and outside that circle.

Mr. J. L. Harris asked the reason for the adoption of the American Gallon in place of the Imperial Gallon, and where the American Gallon came from.

The Chairman (Mr. A. Frank Dabell) in closing the discussion said that, whilst the Author had emphasized the difficulty of truly measuring oil in bulk, he had not put forward a code that could be adopted for application when difficulty occurred.

In the matter of the measurement of impurity the system of taking a one-third sample from top, middle and bottom of a tank was wrong. Assuming a full tank 20 ft. in depth has thrown down 1 ft. of mud, leaving pure oil above, then by the one-third sample system one-third or 33·33 per cent. impurity would be recorded whilst the true figure would be one-twentieth or 5 per cent.

The remedy lies in taking more samples, but the best practice will always be to drain off all impurity.

There is another type of tank which has not been referred to—the bolted tank, which in many cases develops a pronounced bulge between the horizontal seams when full. Such tanks, strapped when empty, must yield generous measure.

Finally, he asked the Author whether, in view of the fact that the co-efficient of expansion varied with the specific gravity of oil, it would not be justifiable to apply generally the figure 38 as a constant for use in correction.

Mr. J. S. Parker, in reply, said that the American Barrel is equivalent to 42 American Gallons, and the Imperial Barrel to 35 Imperial Gallons, and it is generally accepted that the barrel is exactly similar for both measures. Actually it is not, and while the slight difference is of little importance for routine work it becomes significant when dealing with large quantities.

Mr. Trasler has raised the point that one can obtain $\frac{1}{16}$ in. dip accuracy by averaging dips. By adopting this procedure one lowers the experimental error, but it is doubtful whether an accuracy of $\frac{1}{16}$ in. is obtained.

The idea of taking an " all level sample " is good, but the method has certain disadvantages which would tend to give unsatisfactory results.

The point was raised of a bulge on the tank bottom under a standpipe, but this appears to be carrying accuracy to a fine point.

The value of taking as many dips as possible is obvious as by averaging over a number of dips the experimental error is lowered.

It is general practice to strap the tank empty and the fact that in the United States an allowance is made for the bulge in a large tank when full would indicate that this practice is adopted there.

With regard to telescopic and bolted tanks, the principles dealt with for the main types of tanks may be applied to these other types with slight modifications.

The question of taking four temperatures round the tank is interesting and there is no doubt that it will give more accurate results. Even then it does not take into account the temperature gradient from top to bottom. This is difficult to arrive at with any degree of accuracy without a special type of thermometer on the maximum-minimum principle.

Mr. Murray raised the question of the expansion of tank plates with temperature. This is again carrying accuracy to a fine point. Such a correction would be small and difficult to obtain in practice.

The last point raised by Mr. Dabell is not capable of such simple solution as he would suggest. Specific gravity varies in two ways —with temperature and with the quality of the oil. If the quality of the oil is a constant then the co-efficient of expansion and the specific gravity are constants, and the resulting correction factor is a constant. If the quality of the oil is a variable and the temperature is a constant, then the rate of increase of specific gravity is not similar to the rate of decrease of the co-efficient of expansion, consequently the quotient of the two is not a constant.

The meeting terminated with the adoption of a vote of thanks to the Author of the paper and to the members of the Apex Club for the use of their room.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

TRINIDAD BRANCH.

THE FOURTEENTH ORDINARY MEETING of the Trinidad Branch of the Institution of Petroleum Technologists was held at the Club Room of Messrs. Trinidad Leaseholds, Ltd., Fyzabad, on Wednesday, November 27th, 1929, the Chair being taken by Mr. A. Frank Dabell.

In opening the meeting, the Chairman said that three short papers were to be read, and that, if the system of dealing with different subjects, which called for the interest of all present, was appreciated, the principle would be developed.

During the reading of the first paper, the Chair was taken by Mr. H. W. Reid.

Casing Shoes are Unnecessary in Rotary-Drilled Wells.

By A. FRANK DABELL, M.I.Mech.E. (Member).

On a recent occasion the author maintained that the washing of rotary-drilled wells with water before putting them to production was prompted more by precedent than reason. He now suggested that the use of casing shoes, more particularly in rotary-drilled holes, is open to the same criticism.

The original purpose of casing shoes was to reinforce and afford a cutting edge to the lower end of casing columns. So far as reinforcement is concerned, an equal effect may be obtained at a less cost by the attachment of a plain, heavy thread protector which, when screwed tightly on to the lowest joint of a casing string, will afford a flat surface to seat upon the base of a drilled hole or the shoulder of a hole of reduced diameter. For the purposes of water shut-off this flat surface should, under a weight of 10 to 50 tons, press its way into any plastic formation with less risk of deformation than when weakened by a cutting edge. Moreover, when a cementation is made, the form of a protector affords a shoulder giving support to the base of the ring of cement. Further, the fact that a plain reinforcing ring does not extend below the casing precludes the possibility of its being screwed off when drilling out the cement plug, a risk to which a casing shoe is always liable.

In the early days of drilling, the cutting edge of a shoe was relied upon to cut away any projections left in an imperfectly drilled hole.

To-day the cable tool driller scorns the idea that he needs this reaming feature, whilst the rotary driller knows that if once a string of casing cuts the wall of a drilled hole he risks having to drill a new hole from that point.

For this reason it is now common practice to insert plugs in the shoe to ensure that the casing shoe shall not cut and enter the walls.

If, therefore, a cutting edge to a casing shoe is rather a danger than an advantage during lowering, and actually introduces an element of weakness when seating casing, then casing shoes in their old form should be discarded.

DISCUSSION.

Mr. L. A. Bushe said that he thought that having a hardened steel shoe at the end of a column of casing was far more likely to strengthen that string than to weaken it. One disadvantage of using a thread protector is that it is very difficult to find a straight rotary hole below 1000 ft. Having a casing shoe which is chamfered at the bottom and shouldered, there is nothing for tool joints, drill-pipe couplings, or other tools to catch in when they are being pulled out of the hole. This would not be the case if a thread protector were used. A casing shoe afforded the same shoulder as a thread protector, the outside diameter of which would be the same as the outside diameter of the common casing shoe.

He agreed that a sharp casing shoe was apt to throw a string of casing out of the hole; the sharp shoe digs into the wall of the hole and gives a great deal of trouble in getting the casing down. Therefore a guide plug is always used, although the sharp edge of the shoe is useful when spudding casing into formation to obtain a formation shut-off.

Mr. W. Payne said that he thought that the casing shoe was an essential feature in running lengthy strings of casing, when float plugs are used particularly, and where back pressure valves are used in cementing. It seemed to him that the casing shoe would withstand the strain better than a protector, the use of which appeared to be rather a risky business as, unless specially made, a protector is not a tight-fitting joint and might become loose.

A type of casing shoe used quite extensively is the "balloon" casing shoe, which is oversize to eliminate the sharp cutting edge and to increase the surface about four or five fold, a big advantage in a soft formation.

He thought that, in the cementing of wells, a shoe would tend to strengthen the cement around the base of the column. The casing shoe acts as a guide in running in the hole and, if the proper type of shoe were used, there should be no occasion when it would hang up.

Mr. J. L. Harris said that one advantage of the ordinary type of casing shoe was that it prevented distortion of the pipe. A casing protector is designed to protect thread and, if there is any pressure when lowering casing, there will be considerable chance of distorting the pipe if there is no shoe on the bottom.

Mr. H. W. Reid said that he endorsed the opinions already expressed regarding the twisting-off of shoes and the crushing or distortion of the base of the column of casing.

Mr. A. Frank Dabell, in reply, said that the expression " thread protector " brought forward the point at issue which, in the present case, was that something could be used on the base of a casing string which cost less than the standard type of casing shoe.

He was prepared to grant the point that the average thread protector was not good enough to replace a steel shoe, but not that the steel shoe must afford greater strength than the equivalent of a thread protector. It is only necessary to increase the thickness of the equivalent of the thread protector to obtain the same strength as the shoe.

Mr. L. A. Bushe had said that a hard steel shoe strengthens the casing, but a mild steel ring could be made of such strength that it would give the same effect. He also said that a shoe prevents tool joints, etc., from catching up when pulling out. When casing is lowered into a rotary-drilled well, in most instances a tapered wooden plug is fitted in the shoe and is not drilled out until the casing is set on its seat. Therefore, it is difficult to imagine tools being guided into that casing column by this sharpened shoe; it could only be so when a hole is badly bent immediately below the shoe. The point might apply in the case of cable drilling where the casing is suspended during drilling, as in this case the casing is hanging and the tools are being drawn into it.

Mr. L. A. Bushe (interposing) said that theoretically the drill-pipe should not catch when being pulled into the casing, but many drillers have experienced this trouble. It was caused by the hole not being vertical, and every time the tools are pulled out or run in the wall of the hole below the casing is rubbed by the drill-stem until the bottom of the shoe is exposed. He could quite see Mr. Dabell's point that the shoe is on a seat and, therefore, theoretically there should be no chance of the pipe catching.

Mr. A. Frank Dabell (continuing) said that in the case of a hole lying 4° off the vertical and the drill-pipe lying on one side, the rub is more likely to be on the casing than on the shoe, as with a shoe 16 in. long there is only 8 in. of steel exposed at the bottom.

It was also suggested that a casing shoe affords the same shoulder for cement to rest upon as a thread protector. That is hardly the case, as the shoe is made to facilitate withdrawal from the hole and there is no sharp shoulder. He recommended that a shoulder be left to afford a substantial base for that hard ring of cement put down for water shut-off or strengthening purposes.

It is true that welding on the shoe reduces the risk of unscrewing, but the same applied to the equivalent of a thread protector.

Mr. Payne had contended that the higher quality of metal in the shoe is better, particularly in formation shut-offs. The same applies to the equivalent of the thread protector. It is the cutting edge of the casing shoe which is unnecessary in a rotary-drilled hole because, if that cutting edge once impinges upon the wall of the hole during insertion, the probability is that when drawn back and the tools run in to drill over the obstruction a new hole will be drilled from that point downward.

The point raised by Mr. Harris that a shoe prevents distortion of the pipe and affords a factor of safety would also apply to a thread protector.

In introducing Mr. O. F. Nothnagel, the Chairman said that, at the last meeting, a question had been raised as to the true relative value of the United States and Imperial barrel.

The Capacity of the Barrel.

By O. F. Nothnagel.

Besides giving reasons for suggesting that the qualifying of the unit "barrel" should be unnecessary, it is proposed to advance reasons to show that the capacity of the barrel should be regarded as being 34·9735 Imperial gallons and not 35, as commonly thought.

Both the British and American Laws hold definite provisions for the measurement of commodities in gallons. The British Imperial gallon is defined under Section 15 of the Weights and Measures Act, 1878; the American gallon is defined by the United States Bureau of Standards in their Circular No. 154. The methods of arriving at this unit of volume being different one from the other, there results a difference in the volume of an Imperial gallon as compared to an American gallon. This difference is generally recognised as follows:—

1 Imp. gal.=1·20091 Am. gal.
1 Am. gal.=0·8327024 Imp. gal.

The unit of measurement "barrel" originated in the United States of America and is legally recognised throughout that country.

The generally used method of converting Imperial gallons to barrels—i.e., dividing by 35—has as its object alignment with the barrel as defined by the U.S. Standards. The use of this figure does not, however, result in exact conformity with the barrel of 42 American gallons. The correct figure is 34·9735 (providing that the equivalent, 1 Imp. gal.=1·20091 Am. gal., is correct). If the qualifying term "Imperial" is used in relation to the unit "barrel," such term must be recognised as a warning of error in the conversion figure "35" used.

This claim may give rise to much argument, but a parallel case drawn in relation to any unit of measurement which originates in any foreign country will illustrate the danger of confusion resulting from this procedure. For example, if the Russian pood were dealt with as a unit of measurement as extensively as the barrel, would the procedure be to approximate, however closely, the number of Imperial gallons equalling one pood and, because of the error through approximation, qualify the resulting erroneous pood as being an Imperial pood?

One text book in the Petroleum Industry ("Petroleum Engineering," by Phelps and Lake) recognises the figure 34·9735 as being the number of Imperial gallons in one barrel. This book also uses the terms "Canadian" and "United States" in relation to barrels in their tables, the Canadian barrel being equivalent to 35 Imperial gallons.

Returning to the equivalents used above, 1 Imp. gal.=1·20091 Am. gal., W. Moller Fernau ("Petroleum Times," April 6, 1929) shows that the capacity of the Imperial gallon equals 276·800 cu. ins. and the American 230·667. These equivalents would yield the result, 1 Imp. gal.=1·2 Am. gal., in which case the figure 35 would be correct for conversion of Imperial gallons to barrels. It is not clear, however, how Moller-Fernau evades the fact that the American gallon, as defined by the U.S. Bureau of Standards, is distinctly based on a volume of 231 cu. in.

In conclusion it is submitted: (1) that there should be no necessity to qualify the unit "barrel" as being American or Imperial; and (2) that whatever unit of measurement is being converted to barrels, such conversion should be carried out to produce the barrel equivalent to 42 American gallons.

DISCUSSION.

The Chairman, **Mr. A. Frank Dabell**, said that he strongly supported Mr. Nothnagel in this case. There is no justification for the expression "Imperial Barrel." It is generally understood that 35 Imperial gallons are equal to 42 American gallons, but it has been shown that this does not agree based on cubic inches.

Mr. H. W. Reid said that shipments made from Trinidad are all calculated by weight and this is arrived at by Imperial gallons; the factor of barrel does not enter at all, and he imagined that barrels were only an approximation used from field to field. Although it is admittedly the best thing to be strictly accurate in all measurements, the extra calculation involved would hardly be worth the trouble.

Mr. B. McL. Craig said that he regarded the barrel purely as a container and not as a measure. Measurements should be stated in terms of weight (tons or pounds) or in volume (Imp. gals.). In considering the capacity of the barrel, the cubic inch is the only standard which can be used. As an American gallon contains 231 cu. in., the volume of an American barrel would be 42 American gallons, and he agreed with Mr. Nothnagel that this figure should be taken rather than introduce the figure of 230·667 suggested by Moller-Fernau.

Mr. O. F. Nothnagel, in reply, said that Mr. Reid had raised the point that the unit "barrel" is little used in the selling and movement of oil, but he disagreed with him. The barrel as a unit of measurement in the oil industry is becoming more and more widely used. He desired to point out to Mr. Reid that the objects of the paper were principally to prove, first that there should be no necessity to qualify the unit "barrel," and, second, that whatever unit of measurement was being converted to barrels, the number of units should conform to the barrel of 42 American gallons.

Mr. Craig had suggested that the barrel should not be used as unit measurement at all, but the United States, the largest producer of oil, conducts all its dealings in terms of "barrels."

Throughout the paper, no definite comparison of the American and Imperial gallon has been given, because at least three different figures have been found. The one used here is published in the Phelps and Lake text-book, and is taken on that proviso. If Moller-Fernau is to be believed, then he creates an Imperial gallon which is equal to 1·2 American gallon, in which case 35 is the exact figure to be used for conversion of Imperial gallons to barrels.

Mud Flow.

By C. C. Wilson (Associate Member).

The subject of mud flow is confined to flows found below the surface, as opposed to the extensive sheets of mud which have been extruded along the crest of the Southern Range anticline, exemplified by the Palo Seco mud volcanoes.

Sub-surface, or fossil, mud flows have been found in a number of wells and in surface exposure in the Palo Seco oilfield and are confined to the zone of the Cyclammina clay.

The point to be accentuated is that of intrusion of mud after deposition as opposed to extrusion during deposition on the bottom on a shallow sea or lagoon. Evidence for intrusion arises from the fact of variation of horizon of the occurrence of flow, when referred to the base of the Cyclammina clay, the latter being accepted as a well-defined marker horizon. The fact that these flows are found at different levels indicates that they have followed lines of weakness formed during the main period of folding and have spread out in a laccolitic type of intrusive within the softer bands of the clay.

The Cyclammina clay is everywhere recognised as a zone of weakness suffering considerable imbrication, seen in numerous exposures and well cores.

It is hard to conceive any reason for the extrusion of mud during the deposition of the clay zone particularly, and as fossil flows in this locality are confined to this zone, it seems more reasonable that intrusion during the folding was the real cause of their existence.

No attempt is made to explain the origin of mud flow, but this is a convenient opportunity to express the view that mud flow is not due to enormous pressures of confined gas pockets, but to the squeezing of beds containing gas, oil and salt water along planes of tectonic movement.

If extrusion of mud during the deposition of the Cyclammina clay zone took place, it is hard to visualise any reason for their outlet through unfolded beds.

The source of the mud is, without doubt, the Oligocene or Lower Miocene as seen by its fossil content of Globigerina suggesting the marls, and by the frequent occurrence of pebbles characteristic of the Herrera Sandstone type.

The intruded flows, therefore, have passed through all the principal oil horizons known in south-western Trinidad, and it is believed that lower oils have been carried up by these flows, or that these flows have opened channels along which lower oils have migrated.

It is interesting to note that in the vicinity of mud flow in Palo Seco the oil is of noticeably higher grade than in areas away from the flow, suggesting that an admixture of migrated oil has occurred in the former case.

A parallel case is suggested at Guayaguayare where similar phenomena obtain. At Fyzabad, where the oil throughout is

heavier than at Palo Seco and Guayaguayare, there is a remarkable absence of mud flow.

An example of the variation of gravity at Palo Seco is given by a number of wells showing mud flow whose oil is 0·83 sp. gr., as compared with distant wells showing oil of 0·90 to 0·92 sp. gr.

In the author's opinion these remarks indicate a strong argument in favour of migration of oil by intrusive mud flow.

DISCUSSION.

The Chairman, **Mr. A. Frank Dabell,** said that he felt that thanks were due to Mr. Wilson for the reasoned suggestion that light oil in upper sands is due to infiltration from the lower for, given its acceptance, it defined a forward step in development.

Mr. J. L. Harris said that the phenomenon of mud flow intrusions is not confined in Trinidad to Palo Seco. Mud flows have a very important bearing on the accumulations of oil and on the migration of oil. He would not like to make any definite remarks about the subject except that, in the Fyzabad area, there is no positive evidence of mud flows, but he had no doubt that some are present.

Mr. L. A. Bushe said that he took it that at Palo Seco these mud flows have been encountered in cores. He desired to ask if the author had arrived at any thickness of the mud flow.

Mr. C. C. Wilson, in reply, said that bands of flow varying from 5 to over 20 ft. in thickness had been encountered. In some cases where the coring had started in the flow it has continued for 20 ft., and it may have occupied a considerable thickness above the beginning of the coring. Mud flow is an unstratified clay or sandy clay containing pebbles of marl obviously from the lower marly series which contain foraminifera from beds which are stratigraphically below the producing horizon.

A vote of thanks was accorded to the authors of the papers, and to the members of the Trinidad Leaseholds Forest Reserve Club for the use of the building.

Technology and Economics of the Edeleanu Process for the Refining of Mineral Oils.*

By G. Cattaneo,

The refining of mineral oils is understood to comprise in general the purification of oil by means of chemical action with acid or alkali. Chemical refining, which was formerly exclusively employed, must first be briefly explained in order to show what disadvantages are associated with it and whereon rests the great advance which the process invented by Dr. Edeleanu has established.

Crude petroleum is a mixture of a number of hydrocarbon compounds, and the composition of this mixture varies from place to place and even changes in composition in the same place in the course of time.

The crude oil is split up by means of fractional distillation into lower and higher boiling-point fractions. The lowest boiling-point fractions are defined as benzine (light benzine, heavy benzine); those boiling somewhere between 150° C. and 300° C. as kerosine (illuminating oil) and the highest boiling-point fractions according to the use made of them as lubricating oil, gas oil or fuel oil.

The distillates so obtained are, as a general rule, not ready for use but still contain substances to which undesirable qualities are attached. To remove such troublesome constituents from the distillates is the function of the refining process. In chemical refining, the distillate is treated with sulphuric acid (H_2SO_4), by means of which the chief constituents of mineral oil distillate, namely, the paraffin and naphthene hydrocarbons, are hardly attacked at all, but only the unsaturated compounds and asphaltic substances whose removal is desired. The mixing of the distillates to be refined with the acid takes place in agitators whereby both liquids are thoroughly stirred, either mechanically or by means of compressed air. Acid tar, produced by the combination of acid with the constituents which are to be separated from the oil, is deposited in the agitators, constituting a by-product, the further treatment and disposal of which involves considerable difficulty.

The acid-refined distillate needs an after-treatment with alkali, so that the residual acid compounds are converted to salts and removed by washing.

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* Translated from the German. Paper read before the German Society of Refrigerating Engineers.

In consequence the part of the distillate separated by chemical refining and the acid used are thrown away in the form of an objectionable by-product.

Dr. Edeleanu discovered a method of refining by which the destructive chemical refining of mineral oil distillates is replaced by a physical extraction without loss. The occasion for speaking about the Edeleanu process to this assembly is on account of the rôle which refrigeration plays in the process, and of the interesting fact that a fluid which has been well known for decades as a refrigerant is found to be also a refining agent.

Dr. Edeleanu examined the behaviour of the hydrocarbon compounds found in crude oil, and in the distillates derived therefrom, under treatment with various solvents and found in sulphur dioxide (SO_2), and thus in water-free sulphurous acid, a fluid which dissolves the aromatic and unsaturated compounds while paraffins and naphthenes are hardly dissolved at all. Edeleanu found further that, by reducing the temperature sufficiently, he could prevent entirely the solution of the paraffin and naphthene hydrocarbons in sulphurous acid and arrange that only aromatic and unsaturated hydrocarbons went into solution.

Edeleanu conducted his experiments on Rumanian kerosine distillate, which possesses an aromatic content of up to 25 per cent. and which produces in consequence, when burnt in a lamp, a heavy coating of lampblack. Removal by chemical refining only succeeded with such distillate if fuming oil of vitriol were used and thereby a large part of the distillate lost. By treatment with liquid SO_2 an extract composed of aromatic compounds without loss was produced if the temperature at which the distillate was mixed with SO_2 was reduced to about *minus* 10° C. After mixing, two liquid layers of different specific gravities were formed, of which the upper consisted of refined oil saturated with SO_2 (sp. gr. between 0·9 and 1·0) and the lower of a solution of extract in SO_2 (sp. gr. 1·3 to 1·4). As a visible surface of separation formed between the refined oil and the extract, it was an easy matter to draw off the two liquids separately.

It was then only necessary to evaporate the sulphurous acid out of both liquids in order to obtain refined oil and extract as finished products.

The happy stroke which Dr. Edeleanu made in selecting SO_2 as the solvent thereby again became evident. On account of the low boiling-point of SO_2 (−10° C. under atmospheric pressure), it can be driven off (all but a small trace) without vaporising more than a negligible part of the hydrocarbons. If the process is carried out in a closed system the evaporated SO_2 can be condensed and recovered almost completely.

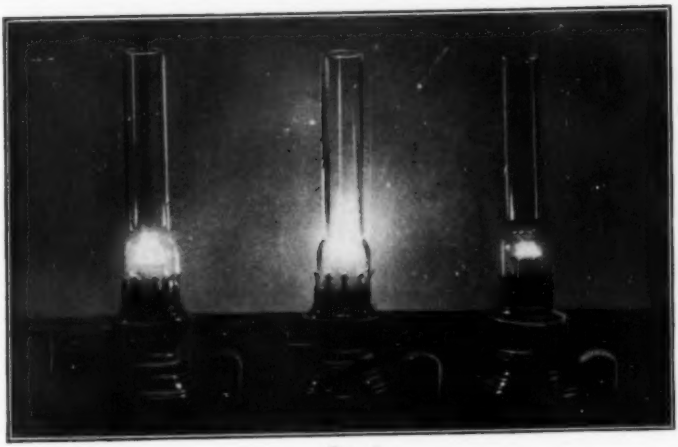

FIG. 1.

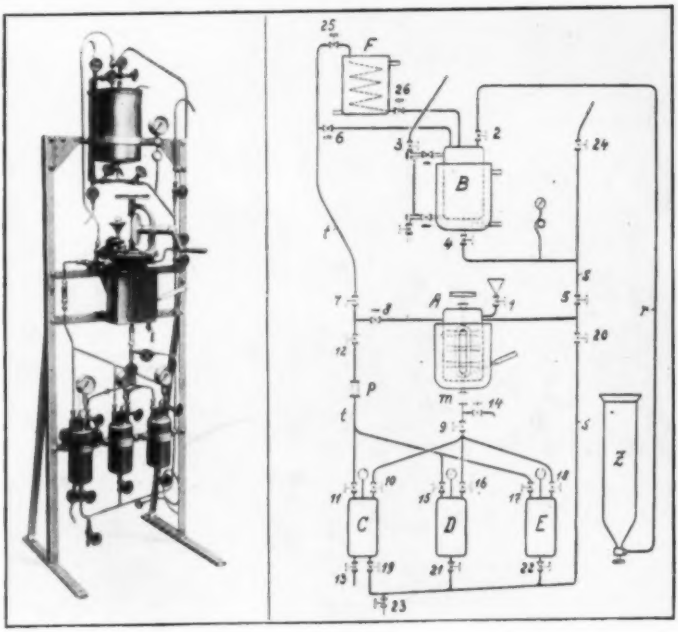
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FIG. 5.

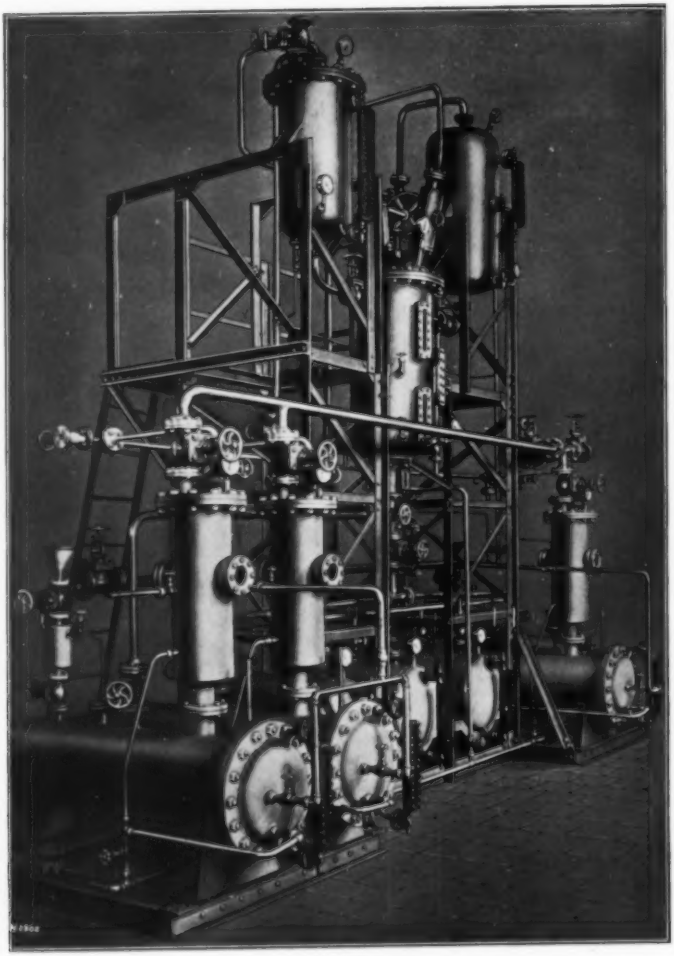


FIG. 6.

Edeleanu obtained from a Rumanian kerosine distillate (Bustenari) of sp. gr. 0·819 about 75 per cent. refined oil of sp. gr. 0·803 and 25 per cent. extract of sp. gr. 0·865. The heavier hydrocarbon compounds go to the extract, so that the refined oil is of less specific gravity. That the soot-forming hydrocarbons are contained in the extract is shown in Fig. 1, which portrays a visible burning test carried out in three similar lamps, of which the first is filled with untreated distillate, the second with refined oil and the third with extract obtained from the SO_2 process.

On this basis the process was taken up in 1908 by the Allgemeine Gesellschaft für Chemische Industrie m.b.H. in Berlin and developed, in conjunction with Messrs. A. Borsig in Berlin-Tegel, for industrial use. After the war the Dutch firm of N. V. Comprimo in Amsterdam took a part in the further development of the process and of the apparatus.

The construction of the first plants was based on the process already proven in the laboratory. An apparatus was used which consisted essentially of five parts, a distillate cooler, an SO_2 cooler, a mixer, a refined oil evaporator and an extract evaporator, as shown in the layout given in Fig. 2. The two coolers were filled, one with distillate, the other with liquid SO_2; both liquids were cooled (by means of pipe coils connected to a refrigerating machine) down to the treatment temperature (–10° C.), the cooled liquids passed into the mixer were stirred and the mixture was allowed to settle and the extract and refined oil were then drawn off into the evaporators one after the other. The SO_2 was drawn off from the evaporators, by warming with heating coils, straight into an SO_2 condenser and the last traces were removed by drawing off by means of one of the compressors and forcing the evacuated vapour into the condenser.

Cold-exchangers had already been introduced into the first plant in which the liquids to be cooled met the liquids to be heated. By this means refrigeration was economised and power consumption reduced.

This first plant worked discontinuously. The five parts were filled and emptied during each operation, the pumps started and stopped and a large number of valves periodically opened and closed. Also the heat exchangers worked intermittently and were therefore not made the most of.

In spite of these unfavourable working conditions, the safety of operation of the apparatus was satisfactory from the very beginning. As the firm, responsible for construction, had at its disposal many years' experience in the construction and operation of sulphurous acid refrigerating machinery when they took up the manufacture of of Edeleanu plants, the construction of the apparatus as required

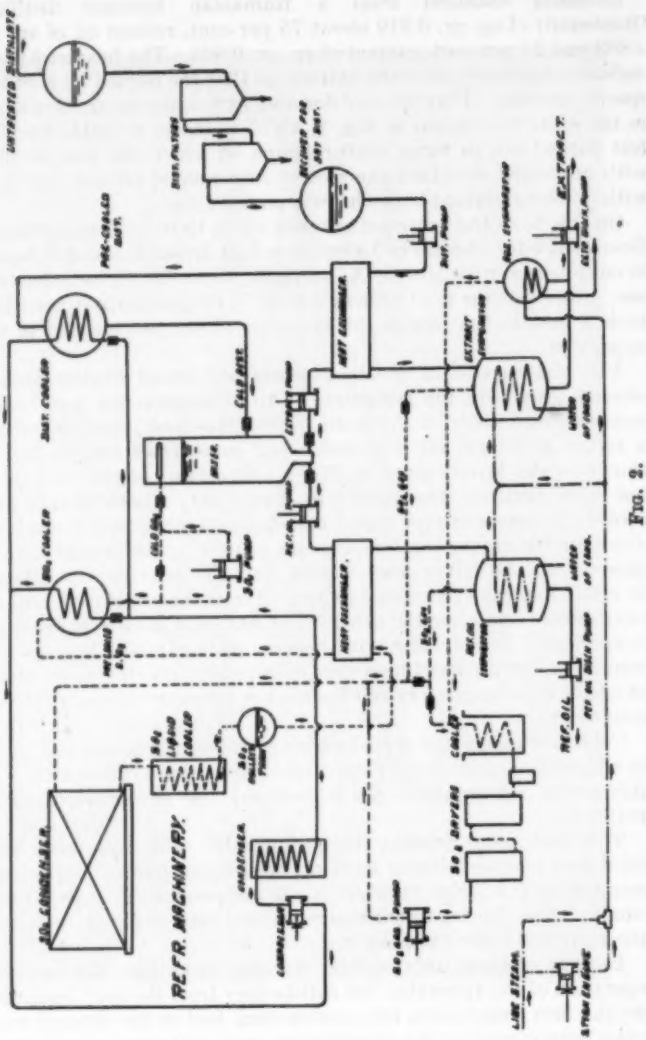


FIG. 2.

rested on a safe basis. The choice of SO_2 as a refrigerant was obvious.

As the layout in Fig. 2 shows, in the early plants the refrigerant was put through a cycle independent of the rest of the plant in order to prevent any contamination of the cooling medium by the distillate to be treated or by moisture contained in the distillate. As the fear of contamination diminished with the improvements in subsequent plants, the SO_2 evaporated by the refrigeration, and that drawn off from the refined oil and extract, were collected together and the liquid SO_2 was no longer cooled by means of pipe coils in the SO_2 cooler but by direct evaporation of SO_2 from the surface of the liquid. That a considerable economy was effected by this means in construction and working cost needs no further explanation.

As the layout in Fig. 2 shows, the SO_2 compressors and the liquid pumps were driven by a steam engine of which the exhaust steam served to heat the evaporators. As the load on the steam engine altered in consequence of the starting and stopping of the compressors and pumps during each operation and as the periods of greatest load of the engine did not correspond with those of greatest demand for heat by the evaporators, the available heat in the exhaust steam was only partially made use of. It was actually necessary to add fresh steam. At that time, for the refining of one metric ton of kerosine distillate with 75 per cent. by volume of SO_2 (about 130 per cent. by weight SO_2), about 600 kilograms of steam were needed.

In spite of the imperfect economy of the apparatus and the high consumption of steam, the pre-war Edeleanu plants proved profitable when dealing with distillate of high aromatic content whose chemical refining would have entailed still higher cost. It was, however, clear that the economy of the process would be considerably improved if one were successful in running the plant continuously.

Benefits to be expected from the continuous process were: A greater throughput for a given size of plant, economy in steam, lower repairing costs when the periodical alteration in pressure and temperature with its detrimental effect on the apparatus was omitted, and an important simplication and cheapening of the operation.

Fig. 3 shows diagrammatically a continuously working Edeleanu layout for the refining of kerosine and other light distillates. The evaporators are in three successive stages. From the first stage the sulphurous acid is delivered straight to the condenser. From the second stage the SO_2 is drawn out by aid of a compressor and after the resulting compression likewise reaches the condenser. The last stage works under vacuum. A vacuum pump draws the last traces of SO_2 away and compresses them to the pressure of the

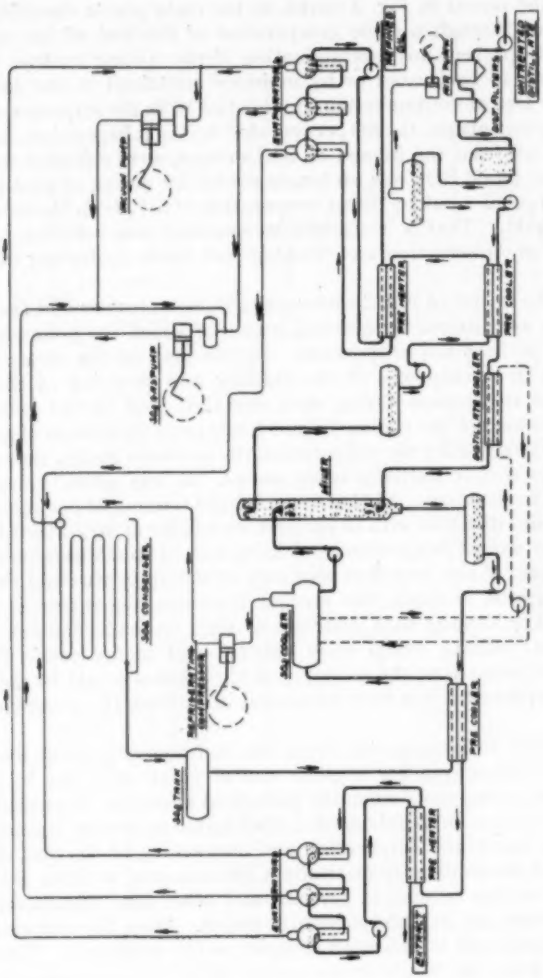


FIG. 3.

second stage, after which they are drawn in by the compressor, with the vapours derived from the second stage, and compressed to the condenser pressure. By the application of two-stage compression, compressor volume and power is saved and also the maintenance of a good vacuum made easier.

Besides cold exchangers, heat exchangers were introduced into the process as a further improvement, in which the solutions coming from the mixers were warmed up in counter-current with the products pumped away from the last evaporators.

The plant, which was first run continuously in the year 1924, fulfilled all expectations although the mixer at that time was still operated intermittently and only the cooling, evaporating and liquefaction were worked continuously. The exhaust steam from the engine driving the compressors and vacuum pumps just sufficed for the heating of the evaporators. For the treatment of one metric ton of distillate with 75 per cent. by volume of SO_2, only 350 kg. steam were necessary instead of 600 kg. with discontinuous evaporation.

Electrically driven centrifugal pumps were installed for the first time as liquid pumps with special stuffing-box construction for dealing with liquids containing SO_2. The power consumption of the pumps amounted to about 5 k.w. hr. per ton of distillate.

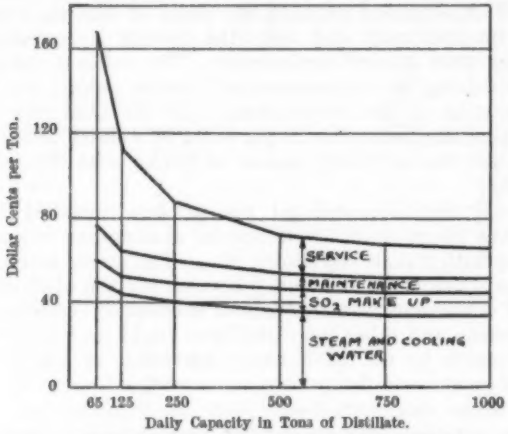
After a continuous mixer had been successfully constructed in which kerosine and other light distillates could be refined just as well as formerly by the intermittent treatment, all further plants were built on the completely continuous system.

Fig. 4 shows diagrammatically how the running costs of the continuous arrangements appear for various daily throughputs. The costs are based on American practice in dollar-cents per ton treated. The high wages in America lead to the use of as large plants as possible, as with these the service costs stand lower per ton of distillate treated than with small layouts. The consumption figures upon which the diagram is based are guaranteed by the builders and proved by trial runs of more than a week's duration. The guarantees of the whole of the plants as regards performance were completely fulfilled, indeed it even turned out that the consumption of steam, electrical energy, water and sulphurous acid were actually less under working conditions than as guaranteed. In consequence the working costs shown in the diagram can be reckoned as maxima which will be reduced under normal working.

The continuous process in conjunction with the recovery of heat and cold and the utilisation of waste heat from the prime mover fulfilled the requirement of good economy in energy and heat, provided that the plant was driven by steam engine. There came, however, in American refineries more and more into the foreground

the demand for electric drive. This demand arose partly from the objection to a steam engine and its necessary transmission gear, partly from the fact that electric energy was especially cheap (e.g., in California from water power), or that in the refinery a steam power plant was available which could provide driving power for the Edeleanu equipment in the form of electric current, and steam for heating the evaporators as draw-off steam.

As such central power plants with modern steam turbines have essentially a smaller steam consumption per horse power hour



RUNNING COSTS ON THE EDELEANU PROCESS.
Based on American practice treatment of kerosine distillate with 75 vol.% of SO_2 (steam drive 1926).

FIG. 4.

than a steam engine could show, which was provided only for the Edeleanu plant and which was working with back pressure, it followed that the equilibrium reached in steam-driven Edeleanu plants between power and heat (between steam demand of the engine and steam demand of the evaporators) was no longer attainable. It therefore became necessary to try to reduce the heat requirement of the evaporators.

Independently of that, the necessity of reducing the heat requirement of the plant appeared on account of the refining of lubricating oil distillates which was taken up meanwhile.

Such distillates have to be treated with considerably greater quantities of sulphurous acid than kerosine distillate. According to the character of the distillate and the use to which the refined

oil is put, up to 600 per cent. by volume of SO_2 is used in the process. The cooling of this large quantity of SO_2 its evaporation and liquefaction, would necessitate very large apparatus and waste much work and heat. Two methods have been adopted to meet this difficulty and to accomplish economically the treatment of lubricating oils. Dr. W. Hess found that it was possible to considerably reduce the aforementioned SO_2 quantity if the distillate was pre-washed with extract SO_2 solution taken off from the previous operation and after-treated with clean SO_2. If four cycles are allowed to overlap, *i.e.*, if the distillate is first handled with extract-solution from the third previous operation, then with solution from the second previous operation, then with solution from the previous operation, and in conclusion with pure SO_2, one uses only approximately a third of the SO_2 quantity. This so-called counter-current process, invented by Dr. Hess, has proved good in practice.

A laboratory apparatus for the treatment of mineral oils according to the Hess method is set out diagrammatically in Fig. 5. "A" is the mixer, provided with a cooling jacket, into which the distillate to be refined is poured through a funnel with a check valve 1. "B" is a measuring vessel, similarly provided with a cooling jacket, for liquid SO_2 which can be charged from the steel bottle Z. C, D and E are intermediate containers for storing the extract SO_2 solutions. If the extract drawn off is warmed up (by means of a Bunsen burner) in container C, the SO_2 driven off thereby is recovered in the condenser F.

Fig. 6 shows a test apparatus of Dutch design and manufacture. The coolers for distillate and SO_2 are placed at the top, the mixer in the middle, the three extract containers for treating according to the Hess counter-current process are below and beside them the evaporators for vaporising SO_2 from the refined oil and extract. An SO_2 condenser, an SO_2 compressor and a centrifugal pump for returning the intermediate extracts to the mixer are included in this testing plant.

Even with the counter-current process, so much fresh SO_2 is required for treating lubricating oils that the waste steam from its own prime mover does not suffice. For example, a plant for the treatment of 250 tons of lubricating oil with 150 per cent. by volume of SO_2 needed 160 tons per 24 hours of steam for heating, while the engine only yielded 90 tons of exhaust steam. It was accordingly desirable to reduce the heat requirement of evaporation by a half.

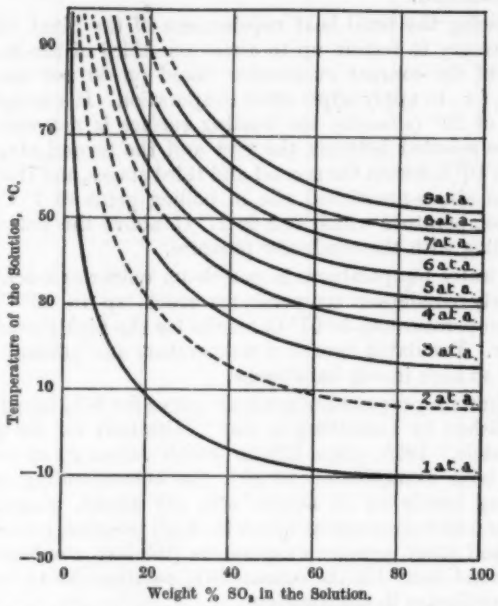
Following the author's proposals it was decided to apply to the process the principle of multiple effect evaporation (hitherto known in connection with the evaporation of aqueous solutions) by the

evaporation of sulphurous acid out of extract SO_2 solution. Before this proposal could be adopted, the behaviour of the solutions in question in the evaporators of the Edeleanu plant had to be closely investigated. As already mentioned, the refined oil is saturated with SO_2 at the outlet from the mixer. The SO_2 content dissolved in the refined oil, and which has to be driven out by heating, is between 15 and 30 per cent. by weight, according to the kind of refined oil, the temperature and the pressure. By far the greatest part of the SO_2 is drawn off with the extract dissolved in it. When treating kerosine distillate with 100 per cent. by volume of SO_2, the extract solution contains about 88 per cent. SO_2 and 12 per cent. extract. In the first extract-evaporator the biggest part of the SO_2 is drawn off under condenser pressure. At the outlet from the first evaporator the solution, if it has been sufficiently heated, contains no more than about 15 per cent. SO_2 and 85 per cent. extract and at the outlet from the second evaporator, from which the vapours were taken off at a diminished pressure, the SO_2 content is reduced to less than 3 per cent. As a result the temperature at which the solution boils, *i.e.*, the SO_2 comes off as vapour, is essentially higher than it would be if it were a question of the formation of SO_2 vapour from pure liquid SO_2. Fig. 7 shows a group of boiling-point curves for a solution of Californian kerosine extract in SO_2. The abscissæ display the proportions (by weight) of the solution, the ordinates show the boiling-point temperatures of the corresponding concentration for pressures from 1 to 9 atmospheres absolute. The abscissa 0 stands for pure extract without SO_2 content, the abscissa 100 for pure liquid SO_2. The temperatures above the abscissa 100 are the known boiling points of SO_2 at the given pressures. The temperature curves proceeding therefrom are plotted with the aid of a number of points experimentally determined in the laboratory of the Allgemeine Gesellschaft für Chemische Industrie. Great accuracy is not essential, as the curves need only provide approximate values on account of the different composition of the mineral oils to be treated.

As the curves show, the boiling point of an extract SO_2 solution of 88 per cent. SO_2 and 12 per cent. extract does not markedly depart from that of pure SO_2. If, however, it is desired, for example, to take off SO_2 from the first evaporator, with a condenser pressure of 5 atmos. abs. (at which SO_2 is liquid at a temperature of 32° C.) to such an extent that the extract leaves the evaporator with only 15 per cent. SO_2 content, the solution must be heated to about 60° C. If the latter be not done, the solution will pass over to the next stage with a bigger SO_2 content and the compressor would have to draw off a greater volume of SO_2 vapour. As this involves a larger compressor volume and causes a higher power demand,

it is economically correct to force up the temperature in the main evaporator as high as can be done without other disadvantages.

As by far the greatest quantity of SO_2 is vaporised in the extract evaporator, which works at condenser pressure and therefore also needs most heat, here is the place where multiple effect evaporation can ensure a saving of heat. As is known, the operation of multiple



PRESSURES, TEMPERATURES AND CONCENTRATIONS OF SO_2 EXTRACT SOLUTIONS.

FIG. 7.

effect evaporation depends on evaporating out of solution in the first evaporation a fraction of the liquid to be volatilized, by the addition of heat and by using the resulting vapours for heating the next evaporator. As the vapours cannot be hotter than the liquid from which they are derived, the liquid on changing from the first to the second evaporator is expanded through a throttle valve and is thereby cooled by partial evaporation. The temperature fall must be sufficiently great to ensure the possibility of a sufficient heat transfer from the condensing vapours of the first stage to the liquid which is to be evaporated in the second stage.

As in our case a gradual rise in boiling-point is bound up with the gradual evaporation of the SO_2, which operates against the heat transfer, it is clear that the application of multiple effect evaporation is limited by the concentration of the solution. In general the economical limit rests at about 50 per cent., *i.e.*, at equal parts of extract and SO_2. Thereby a rise in boiling point of about 7° C. is occasioned.

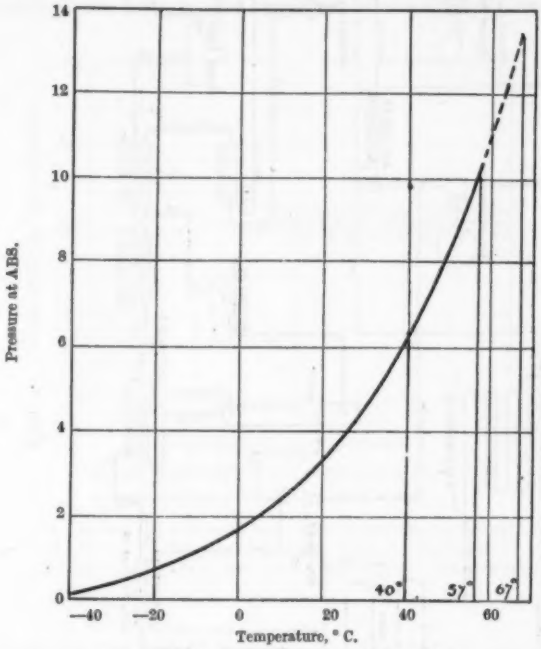
For reducing the total heat requirement of the plant to a half it was necessary to restore up to about one-third of the heat consumption of the extract evaporator based on 50 per cent. concentration, *i.e.*, to apply triple effect evaporation. If a temperature difference of 10° (whereby the heating surface is not unduly increased) be selected between the first and the second stages and in like case 10° between the second and third stages, and if one adds thereto the above-mentioned rise in boiling point of 7° C., there results a temperature which stands 27° C. above the temperature corresponding with the condenser pressure.

Cooling water temperatures in petroleum refineries reach 35° C., consequently condenser temperatures reach up to 40° C., from which a temperature up to 67° C. results for the high pressure SO_2 evaporator. Tabulated figures of temperature and pressure of SO_2 do not go so high in our handbooks.

Fig. 8 shows a pressure-temperature curve for SO_2 based on the table published by Landsberg in the "Zeitschrift für die gesamte Kälteindustrie," 1925, page 179, in which values go up to 60° C. This has been extrapolated to 67°, the corresponding pressure approaching nearly to 14 atmos. abs. (13 atmos. gauge). The temperatures and pressures at which the high pressure, intermediate pressure, and main pressure evaporators (the last combined with the main condenser) for the extract SO_2 solution are to work are shown by ordinates in the drawing.

The multiple effect evaporation takes place accordingly throughout a pressure range which is essentially higher than is customary and established in refrigeration technology. Only in waste heat engines, built about 30 years ago by way of experiment, sulphurous acid was used at such pressures and temperatures, but considerable difficulty was experienced with stuffing boxes. It is worthy of note that our high-pressure evaporation plants, of which the first was put into operation in Hamburg in April, 1927, and the second in the same month in a Californian refinery have worked without trouble from the first and that we had complete success in keeping tight the apparatus, piping and stop valves as well as the centrifugal pumps which had to deliver extract SO_2 solution against a high pressure.

In Fig. 9 is repeated the flow sheet of an Edeleanu plant with multiple effect evaporation. The apparatus in which the SO_2 high-pressure vapours are liquefied and their heat transferred to the solution are of the shell and tube condenser type. Part of the high-pressure vapour is used to pre-heat the extract SO_2 solution almost to boiling point before entering the high-pressure evaporator.



VAPOUR PRESSURE OF SULPHUR DIOXIDE.

FIG. 8.

In the last stage of the multiple effect evaporation a concentration of about 50 per cent. is reached at condenser pressure. Further evaporation occurs by heating with exhaust steam from the prime mover until only about 15 per cent. SO_2 is contained in the extract. The remainder is sucked from the next evaporator by the SO_2 compressor and the last traces are removed in the vacuum evaporator.

The economy of multiple effect evaporation naturally depends on the relation between cost of plant and cost of steam in individual cases. In general it is found by comparative calculation that the

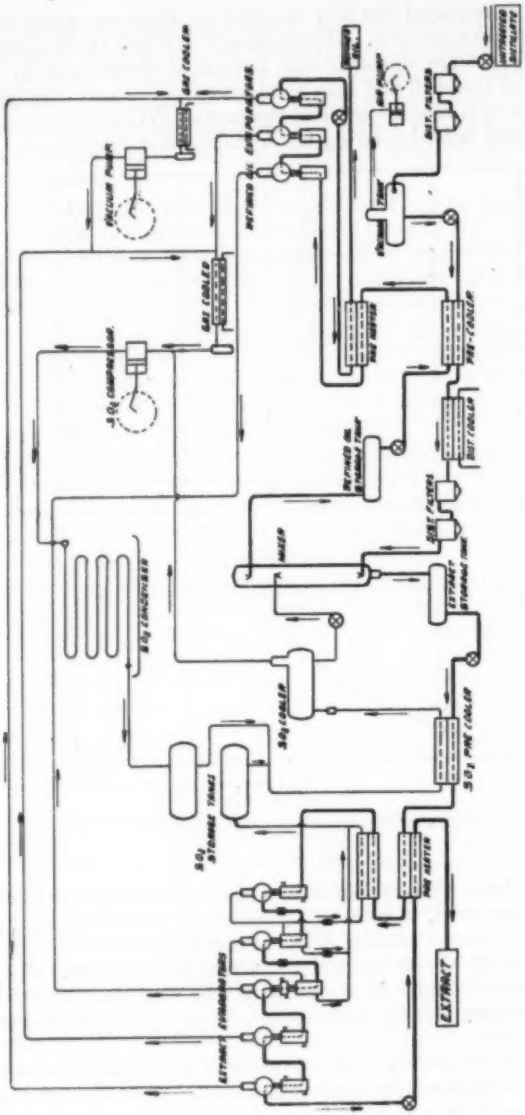
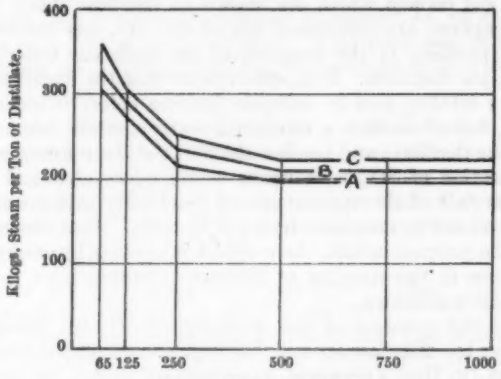


FIG. 9.

process of multiple effect evaporation does not pay for distillates which need a treatment of only 50 per cent. SO_2 by volume. For 75 per cent. SO_2 by volume it is sufficient to introduce one high pressure stage, for 100 per cent. SO_2 by volume and more two previous stages entailing triple effect evaporation are required.

In the diagram Fig. 10, the steam requirement of modern Edeleanu plants for kerosine and light lubricating oils are set out



STEAM CONSUMPTION OF EDELEANU PLANTS.
TREATMENT OF LIGHT OILS WITH :

A. 50 vol. % SO_2 and one-stage extract evaporation.
B. 75 vol. % SO_2 and two-stage extract evaporation.
C. 100 vol. % SO_2 and three-stage extract evaporation.

FIG. 10.

calculated for one ton of throughput. The bottom line refers to treatment with 50 per cent. SO_2 by volume with single-stage evaporation of the extract solution, the middle line for 75 per cent. by volume and two-stage evaporation, the top for 100 per cent. by volume and three-stage evaporation.

Already for plants of medium size a steam demand of only 200 kg. per ton of distillate has been attained for 50 per cent. SO_2 treatment and of 230 kg. for 100 per cent. SO_2 treatment. For steam engine drive this steam quantity is used for driving the compressors and vacuum pumps while the exhaust steam is sufficient for heating the evaporators. The driving of the centrifugal pumps for pumping distillate, SO_2 refined oil and extract demands about 3 kilowatt-hours per ton of distillate for medium-size plants. The running

of the plant is carried on by one foreman and two or three workmen per shift for plants of medium size.

The description of the process and the apparatus constructed for it would not be complete without mention of some complementary details which although not essential to the process are of importance for the trouble-free operation of the plant. It cannot be avoided that in driving out SO_2 from the refined oil and extract, hydrocarbons of low boiling point are vaporised as well. By means of special gas coolers which are shown in the flow sheet, Fig. 9, these oil vapours are condensed out of the SO_2 gas stream. An additional problem is the removal of the moisture entering the plant with the distillate. It is self-evident that the distillate must be dried by settling and by suitable filtering before it reaches the apparatus, but even then a minimum water content remains dissolved in the distillate and reaches the SO_2 *via* the refining process. A concentration of SO_2 with water would cause chemical attack on the materials of the apparatus and machinery and must therefore be prevented by constant drying of the SO_2. That the methods used for the purpose attain their object is proved by many years of experience in the running of Edeleanu plants under the most unfavourable conditions.

Recently the question of the make-up of SO_2 (of which from 1 to 3 kg. per ton distillate are lost) has been simply and economically solved. On Dr. Hess's proposal, gases containing SO_2 are produced in an auxiliary plant by burning sulphur and are passed through an absorption tower being sprayed by the distillate to be treated. The distillate absorbs by this means just so much SO_2 as is necessary for covering the loss.

Thanks to the simplifying and perfecting of the Edeleanu process, which has been attained step by step, it has been possible to cheapen the process so much that it is considered more economical in most cases than the chemical refining of mineral oils. It has been shown how, by rational manipulation of the quantity of energy used for cooling, dissolving and separating, the steam consumption could be brought down to under a half of the original expenditure.

There are numerous manufacturing processes in the chemical industry in which cold, heat and power are used. The example of the Edeleanu process shows what a remunerative field of work the domain of chemical technology offers to the engineer who has learnt to think technically and economically. Intelligent collaboration between chemist and engineer, exchanging knowledge and practice, is required for the technical and economical elaboration of a process originating in the laboratory. Mutual comprehension and joint endeavour will lead their work to perfection, to their own satisfaction and for the benefit of industry.

The Asymmetry of the Yenangyaung Anticline.*

By W. E. V. Abraham, B.Sc., A.R.C.Sc.I., F.G.S.

1. The Yenangyaung Field, in Upper Burma, has for many years been referred to in technical literature[1] as an outstanding example of a symmetrical anticline. This view was supported by such surface dip evidence as could be obtained in and close to the productive area.

2. In 1926 the difficulty of explaining certain facts in regard to the underground concentration of oil and gas suggested the advisability of confirming or amending previous ideas as to the symmetry of the anticline by the construction of cross sections not confined only to the productive area, but extending for very long distances out on the flanks.

3. From the accompanying rough sketch (Fig. 1) it will be seen that the Yenangyaung Field is divided by two main faults, A and B, into a central portion, between these two faults, and two uplifted pitching ends. Three small rivers, the Natsin Yo, the Aungban Yo and the Taungle Yo give good sections through the main central portion and three broad based sections were constructed roughly along the lines of these rivers and at right angles to the general strike of the fold.

4. It should be noted that the Pegu (Miocene) rocks exposed in the central part of the fold are separated by an unconformity from the overlying Irrawaddies (Mio-Pliocene) and that these broad based cross sections had to be constructed partly from dip evidence in the Pegu and partly from dip evidence in the Irrawaddies. Other evidence suggests that this fact is not likely to introduce serious errors as regards the question of degree of asymmetry, etc.

5. Of the three broad based cross sections only the most central one, that along the line of the Aungban Yo, is here reproduced (Fig. 2) exactly as drawn in 1926. It shows that the anticline is not symmetrical, being markedly steeper on the west than on the east.

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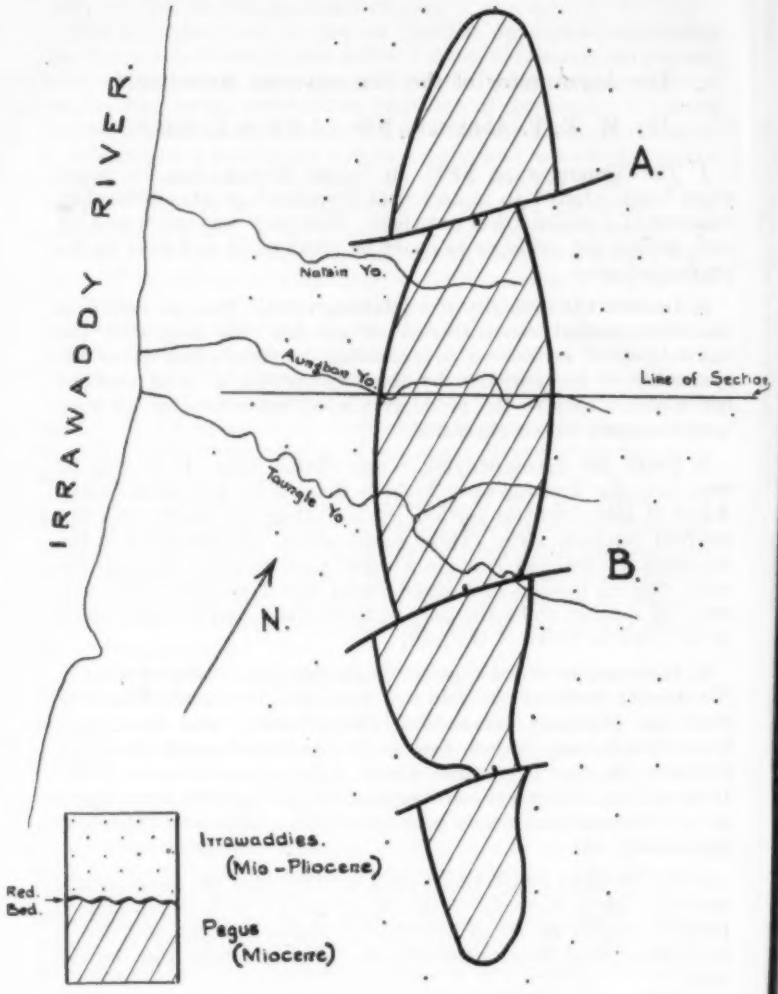
*Paper received June 24th, 1930.

[1] For example, in 1912, in Pascoe, "The Oilfields of Burma," Mem.G.S.I., Vol. XL., part I., p. 66; in 1928, in Busk, "Earth Flexures," p. 70.



SCALE: 1″ TO 1 MILE.

ROUGH SKETCH MAP OF YENANGUAUNG FIELD, UPPER BURMA.

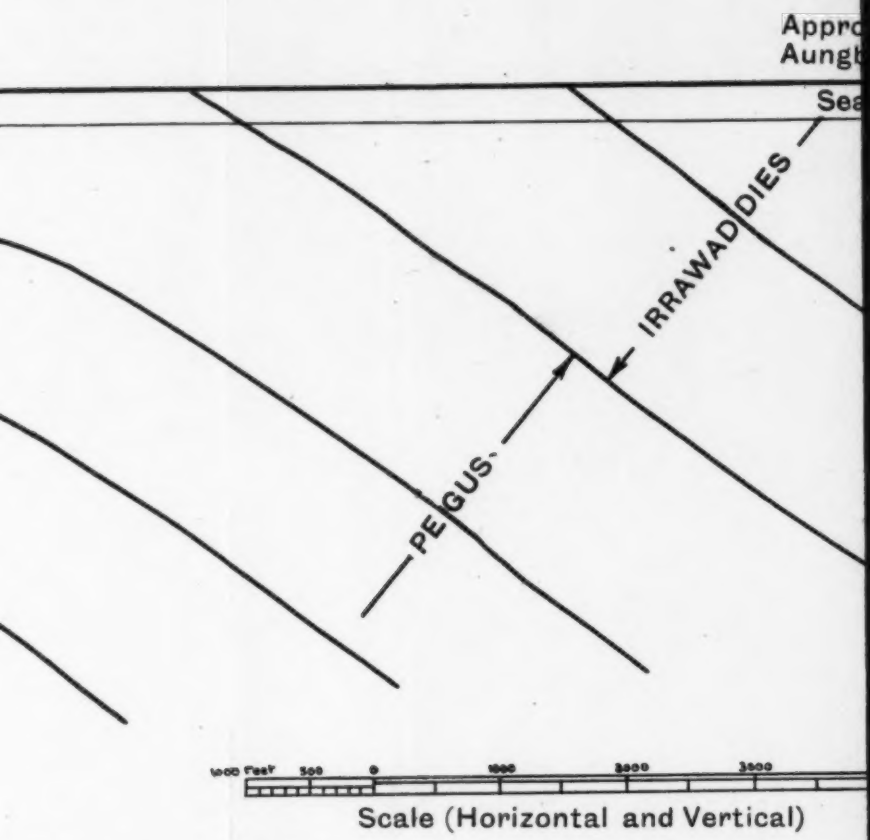
FIG. 1.

S. 60° W.

Red Bed

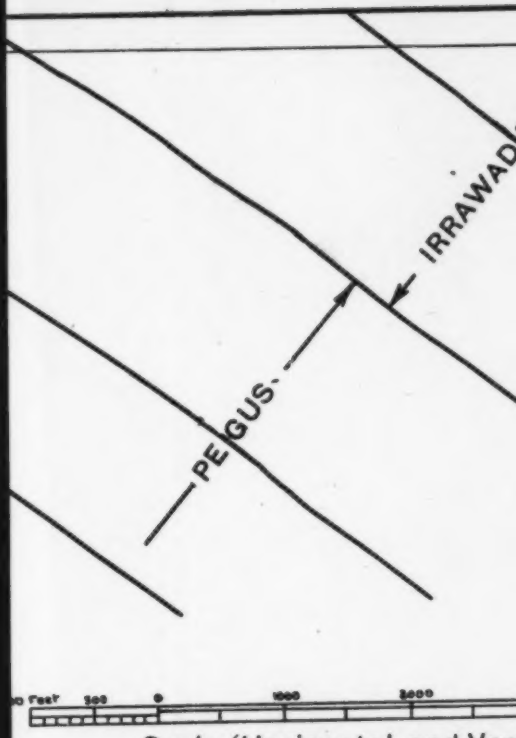
SECTION ACROSS YENANGYAUNG ANTICLINE IN NEIGH

FIG. 2



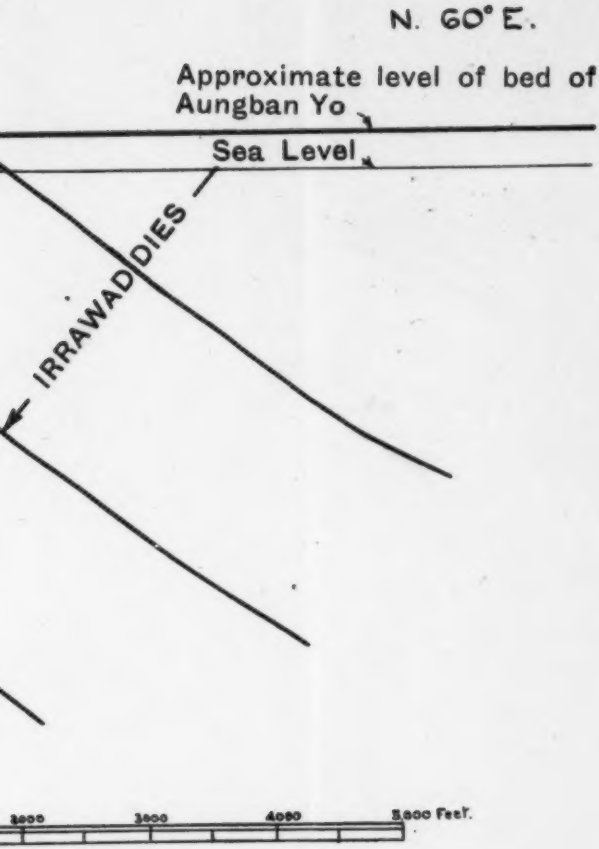
LINE IN NEIGHBOURHOOD OF AUNGBAN YO.

IG. 2



Scale (Horizontal and Ver

OF AUNGBAN YO.



3000 2000 4000 5000 Feet.

and Vertical)

6. It should be noted that this section is drawn, from surface dip evidence, on the assumption of "parallel" folding, that is, no allowance is made for possible thinning of beds. This method of section construction is admirably suited for displaying probable degree of asymmetry, but it will be realised that no such section, based on surface evidence only, can hope to portray exactly structural conditions at depths of 4000 ft. or 5000 ft.

7. The other two sections (not here reproduced) showed :—

(a) That the degree of asymmetry is about the same from north to south of the central portion of the field.

(b) That the intensity of folding increases slightly from north to south of the central portion, i.e., from the Natsin Yo to the Taungle Yo.

8. These results are published by kind permission of the Burmah Oil Company, Limited.

Improvements in the Manufacture of Valuable Products from Coal and other Oxygen-Containing Carbonaceous Materials.*

By H. I. Waterman and J. S. Doting.

The treatment of carbonaceous materials with hydrogen or gases or vapours containing hydrogen under pressure in order to convert the initial materials into valuable liquid products, such as benzine and kerosine, is known. It has also been proposed to replace the hydrogen by other reducing gases or gases which yield hydrogen under the circumstances of the reaction. So, for instance, carbon monoxide alone or together with water vapour or hydrogen has been proposed as a hydrogenation gas for destructive hydrogenation. Numerous proposals have been made for carrying out the said treatment, commonly known as destructive hydrogenation, which differ, for instance, in the nature of the catalyst used for facilitating the reaction, either in the reaction temperature or in the pressure employed, or in other reaction conditions, but all these prior proposals are alike to the extent that the originating materials are heated to a relatively high temperature in the presence of hydrogen or other reducing gases.

In studying destructive hydrogenation of carbonaceous materials of the above-mentioned nature we have found that a considerable part of the hydrogen introduced in the process is consumed for combining with oxygen present in the initial materials and forming water therewith. That part of the hydrogen which combines with the oxygen present in the initial materials is in consequence wasted and only that part of the hydrogen which combines with the hydrocarbons formed during the reaction is utilised for the object in view. The said drawback can be eliminated in the following way.

The original carbonaceous materials are first treated in the presence of carbon monoxide or carbon monoxide containing gases at elevated temperature and preferably under pressure. Thereafter any lower boiling products which have been formed may be removed and then the mass, which is now substantially free from oxygen, is subjected to a second treatment in the presence of hydrogen or gases substantially consisting of hydrogen at elevated

* Paper received June 24th, 1930.

temperature and pressure for a further conversion into valuable liquid products. Suitable catalysts may be employed for facilitating the reaction in both stages. The carbon monoxide may be that obtained from any suitable source. Gases containing carbon monoxide, such as water gas or producer gas, may also be used. The oxygen present in the carbonaceous materials combines with the carbon monoxide, forming carbon dioxide. Part of the oxygen may also combine with the hydrogen present in the carbonaceous materials to form water, which with the carbon monoxide, yields hydrogen according to the equation: $H_2O+CO=CO_2+H_2$. The hydrogen obtained in this way may serve for the hydrogenation of the carbon compounds. Furthermore it frequently happens that the initial materials contain a certain quantity of water which, on heating, is vaporised and combines with the carbon monoxide, as stated above. Sometimes it may even be advantageous to add water beforehand to the materials to be treated in order to increase the quantity of hydrogen originating from the reaction between carbon monoxide and water. The materials to be treated in the first stage are brought into a condition such that on further treatment with hydrogen they can be easily and economically converted into the desired final liquid products.

204 grams of brown coal containing 9·2 per cent. ash and 2·0 per cent. moisture are heated in an autoclave together with a mixture of 15·2 grams of a catalyst consisting of a mixture of simultaneously precipitated ferric hydroxide and aluminium hydroxide, 20 grams of water, and a mixture of equal volumes of hydrogen and carbon monoxide containing 102·5 grams CO, under an initial pressure of 100 KG/sq. cm. In 67 minutes the temperature in the autoclave is gradually raised from room temperature to about 460° C. Immediately thereafter heating is stopped.

The yields were as follow, calculated on dry and ash-free brown coal :—

Hydrocarbon oil boiling below 220° C.	9·6	per cent.
Hydrocarbon oil boiling between 220° and 300° C.	7·6	„ „
Cresolic substances boiling above 300° C.	4·0	„ „
Soft asphaltic residue	38·0	„ „

From the following calculation it appears that the greatest part of the oxygen present in the coal in the form of oxygen compounds is removed in the form of CO_2.

At the beginning of the reaction 27·5 grams water were present (20 grams added as such, 4·1 grams present as moisture in the coal, 1·5 grams in the catalyst, and about 2 grams formed out of the gases during the reaction). These 27·5 grams water correspond to 24·5 grams oxygen. Moreover, 102·5 grams CO, equivalent to 58·6 grams oxygen and 200 grams moisture-free brown coal,

containing 48·2 grams organically fixed oxygen, were present before the reaction. In total, 131·3 grams oxygen, of which 83·1 grams is in the water and carbon monoxide.

After the reaction 11·5 grams of water were obtained, equivalent to 10·2 grams oxygen. Moreover, 41·1 grams CO, equivalent to 23·5 grams oxygen and 120·0 grams CO_2, equivalent to 87·3 grams oxygen. In total, 121·0 grams oxygen; consequently 37·9 grams oxygen are expelled from the brown coal. It may be estimated that the residue contained about 5 grams of oxygen and the cresolic substances about 1·5 grams of oxygen. During the reaction 61·4 grams CO were consumed.

From the small quantity of water which remains after the experiment is completed it is also evident that with this procedure the oxygen from the brown coal is expelled for the greater part as CO_2. In an analogous experiment, made with 100 KG/sq. cm. hydrogen as hydrogenating gas, 32·6 grams water remained. In this experiment the twenty grams of water were not added beforehand, so that at the beginning only 7·5 grams water were present.

The residue is now again treated with hydrogen under pressure, whereby it is converted, to a considerable extent, into lower boiling hydrocarbons. It may be observed that since it appeared that carbon monoxide, or a mixture of carbon monoxide and other gases, is very suitable for the removal of oxygen from carbonaceous materials, the method described may also advantageously be applied to mixtures of coal or the like products and such oxygen-containing materials as normally only need a one-stage treatment for conversion into valuable liquid products substantially free from oxygen. The residue obtained in the first stage is then treated with hydrogen as described above.

CURRENT PETROLEUM NOTES.

Cost of Drilling Deep Oil Wells.—The drilling of an oil well to a depth of more than a mile is an expensive undertaking. All equipment must be unusually substantial and well designed, and many special kinds of apparatus are required.

During the past two years the Petroleum Experiment Station, maintained by the United States Bureau of Mines, Department of Commerce, and the State of Oklahoma at Bartlesville, Oklahoma, has collected data on the Oklahoma City field as part of its general study of oil fields and oil production methods. One of the interesting things in this field is the height of the derricks. Most of them are 122 ft. high, but there is one 136 ft. high, one 157 ft. high and one 170 ft. high; this latter derrick has a 30 ft. base, and is 109 ft. from derrick floor to fourble run-around. A special concrete foundation for the rigs is used in this field.

It is the usual practice to construct two 25 × 6 × 90 ft. slush pits, and one settling pit approximately 90 × 90 × 2 ft., making a total amount of 1600 cubic yards of earth to be moved. The cellars beneath the derricks measure approximately 18 ft. from the derrick floor to the top of the concrete slab. The cost of constructing the slush pits averages about $650, and the cost of digging the cellars is in the neighbourhood of $225, making a total cost of excavation work at each location of about $875.

The general contract price for drilling a 12 in. or 12¼ in. rotary hole and completing the well with an 8¼ in. hole is $11 per ft. For a 6500 ft. well the drilling expense alone amounts to about $71,500.

Fuel requirements for drilling increase rapidly with the depth of the well, and operations in the Oklahoma City pool have proved to be no exception to the rule. Batteries of three 125 h.p. or four 100 h.p. boilers are requiring as much as 500,000 cub. ft. of gas per 24 hours, and the total fuel requirement for completing a rotary well in this district may run as high as 50 million cub. ft. of gas.

The daily water requirements per well in the Oklahoma City district change somewhat with the depth of the hole. Approximate figures from wells now drilling indicate that 3000 barrels of water per day are required for the first 2000 ft. of hole, 2000 barrels of water per day from 2000 ft. to 3000 ft., and 1500 barrels of water per day from 3000 ft. to the total depth of 6500 ft. This brings the total water requirements up to about 140,000 barrels of water to complete a well.

Migration of Natural Gas from Injection Wells.—An investigation of the direction that natural gas migrates from injection wells is being conducted by engineers of the San Francisco field office of the United States Bureau of Mines, and some very interesting facts are being determined. From data collected it appears that gas migrates theoretically fan shape from the injection wells, and that the angle of the fan depends upon the dip of the formation. In a level sand (90° dip) the gas migrates in all directions, and the angle of the gas fan can be taken as 360°. If the formation stands on end (0° dip), the gas theoretically should go straight up and the angle of the gas fan would be 0°. The data further show that the fan angle decreases as the slope of the formation increases. When the slope is about

30° the fan angle is about 100°, and when the slope is 5° the fan angle is 190°. This information should be of real value in locating injection wells, particularly in California, where many oil structures have steep slopes.

APPARATUS FOR VACUUM DISTILLATION OF LUBRICATING AND HEAVY PETROLEUM OILS.—In the course of a recent study of lubricating oils conducted in the laboratory of the San Francisco field office of the United States Bureau of Mines, it became desirable to distil the oils used in the experimental work at pressures as low as 10 mms. (mercury column) absolute. In the effort to overcome difficulties and eliminate sources of error, certain changes were made in the apparatus for vacuum distillation used by the Bureau of Mines for crude petroleum. These changes were described in Report of Investigations 2819, issued in July, 1927. Subsequent to the publication of Report of Investigations 2819 several other changes have been made, and the present form of the apparatus for vacuum distillation of lubricating oils is described in this revision of Report of Investigations 2819. These changes were found to give more accurate checks on duplicate distillations.

A complete description of this apparatus is contained in Report of Investigations 2996, by Martin J. Gavin and Arch. L. Foster, copies of which may be obtained from the United States Bureau of Mines, Department of Commerce, Washington, D.C.

COMPRESSIVE STRENGTH OF OIL SHALES.—Experiments to determine the compressive strength of some of the oil shale strata in Naval Reserves Numbers 1 and 3 have been conducted by the United States Bureau of Mines, Department of Commerce, in co-operation with the State of Colorado in the laboratories of the University of Colorado. Shale specimens of known oil yield were prepared from representative strata. The mahogany shales produce 40 to 45 gallons of oil per ton, and a difference of 5 gallons per ton did not appear to have any marked effect on the compressive strength of this shale. All of the samples tested on this grade failed between 13,700 and 17,600 lb. per square in. Other shales yielding 35 gallons of oil per ton failed at about 13,000 lb. pressure per square in. Shales containing 6 gallons of oil or less failed anywhere between 10,700 and 29,200 lb. pressure. Many of these lean shales contain considerable compact siliceous seams which, when taken by themselves, are much harder than the rest of the bed. A specimen of Australian shale, carrying 150 gallons of oil per ton, was also tested and found to fail at 15,600 lb. pressure. These tests indicate that the compressive strength of oil shales yielding over 30 gallons of oil per ton of shale ranges between 13,000 and 18,000 lb. per pressure per square in., and that lean shales may fail at 10,000 lb. pressure, or they may stand as much as 30,000 lb.

REVIEW.

STRUCTURE OF TYPICAL AMERICAN OILFIELDS. Vol. II. Tulsa, American Association of Petroleum Geologists. London, Thomas Murby & Co., 1929. Pp. xxiii. + 780.

Prefaced by an excellent introduction by Sidney Powers, "Structure of Typical American Oilfields" (Vol. II.), must be regarded as a valuable contribution to the literature dealing with petroleum deposits. In a volume of 717 pages the structures of some 39 oilfields of North America are described and illustrated by distinguished geologists with specialised knowledge of the particular regions discussed. Structures have evidently been advisedly selected to illustrate the variety of features which influence the concentration of oil. Authors have not, however, confined their remarks to geological questions, but have added important information concerning such details as the nature of the oils and their distribution on the structure, the occurrence, character and distribution of water, and often the presumed source of origin of the oil. Gas and its gasoline contents also receive notice in some papers.

Each article is headed with an admirable but brief abstract of the contents, and many summarise the conclusions in a convenient and concise manner at the end. Cross-sections and sub-surface structure contours are plentifully introduced to assist readers in following the text, and typical sectional diagrams showing the succession of strata in the regions reviewed are added in a number of cases.

The papers are arranged in alphabetical order under States and an orderly scheme has been adopted throughout whereby a general description of the locality is followed by a brief history of the field since its discovery, with often some mention of the early difficulties and disappointments. A description of the physiography and topography of the district usually precedes an account of the geology, which latter subject is divided into sections dealing with stratigraphy and structure. Then follows a detailed description of the oil beds and their development and production.

Many authors do not confine their remarks to geological matters, but add valuable data concerning the systems of drilling in use and the casing programmes employed. Occasionally drilling costs are added and references are made to exceptional difficulties met with in development. Production methods are also frequently referred to by the authors when abnormal features have confronted operators. The Ventura Avenue field is named as the most difficult to operate in California, due to exceedingly rugged topography, steep-dipping flanks of a sharp anticlinal fold, swelling formations and high gas pressures to control.

The Bradford field of Pennsylvania and New York is given the prominence it deserves as representing almost the oldest developed oil region in the Union though still being operated profitably by the flooding process. During 55 years some 85,000 acres have yielded 79,000,000 bls. of 0·800 to 0·835 oil, but an additional recovery of from 2000 to 5000 bls. per acre is confidently expected from the flooding system so largely and successfully practised.

Oilfields of major rank described are Long Beach, California, which had produced 191,560 bls. per acre from 1350 acres prior to the development of the deep zone discovered in 1928; Salt Creek, Wyoming, which has 210,000,000 bls. to its credit from 22,000 acres, Cushing and Seminole, Oklahoma, with 300,000,000 and 275,000,000 bls. yield respectively.

Water and Oil analyses are given in many of the papers, and the gas-oil-water relationships on structures are discussed where they have a value for correlation or other purposes. The tendency towards greater official control of oilfield operations with a view to conservation of petroleum resources and the increasing demands for unit operation give the records of gas-oil-water

relationships considerable and world-wide importance. Another further point commented upon in some of the papers is the encroachment of edge water as depletion proceeds. More detailed information concerning the behaviour of edge water in the various fields would have been widely appreciated, as very conflicting views are held concerning the dangers of water influxes on loss of gas pressure and exhaustion of petroleum contents.

Many excellent production depletion curves are incorporated in some of the papers, and in a number the yield per acre to date is given as well as an estimate of the ultimate yield. Amongst the many interesting points raised in the various papers is the importance of "closure" on many folds and the frequency with which it is affirmed that sand conditions rather than structure have determined the concentration of oil. Although surface flexures often reflect those of greater intensity, at depth the folding is often regarded as too insignificant to attribute to that cause the accumulation of oil. The so-called "shoe-string" production belts illustrated by the Madison Oilfield of Kansas exemplifies curious sand conditions thought to represent sand bars in tidal waters on near shore lines in Palæozoic times.

The Florence Field of Colorado is chosen to show how remunerative concentrations of oils can collect and be preserved in gently dipping (2° to 5°) beds of fissured shale. No less than 12,000,000 bls. of 0·876 oil has been abstracted from 1000 wells on the limb of a syncline.

When dealing with the very conflicting and disappointing results obtained from exploring the domes of North-Western Colorado, the author makes the following interesting statement:—"The nature of the hydrocarbons in the different structures and the lithology of the strata in which they occur indicate that the cause of accumulations was not common to all and that the folding and uplift to which they were subjected may have been factors in forming the oil and gas from the original organic material as well as being agents of transportation."

An occasional admission will be found in the various articles that in some of the older fields sub-surface contours on key horizons might be substantially altered if the wells from which the logs were used were surveyed for verticality.

In discussing the forces operative in producing some of the Mid-Continental domes the view is expressed that the general N.E. trend of their major axis and faults encourages the belief that they owe their origin to rotational earth stresses transmitted through the basement rocks. Those folds following no general regularity or system, it is claimed, may owe their origin to differential consolidation of sediments over buried hills.

The book is profusely illustrated, well printed and concludes with an excellent article of 44 pages by Mr. F. S. Clapp marshalling the facts in the various articles and summarising conclusions. The whole work is admirably arranged and can be confidently recommended to all those studying oilfield technology.

A. Beeby Thompson.

BOOK RECEIVED.

A Survey of Scottish Coking and Furnace Coals. T. Gray, T. H. P. Heriot and W. J. Skilling. London: H. M. Stationery Office, 1930. Pp. vi. + 160, with 3 plates and 1 map. 4s. net, postage extra.

This is the fifteenth publication in the series on the Physical and Chemical Survey of the National Coal Resources, issued by the Fuel Research Board, and deals with Scottish coals.

The first 18 pages deal with the methods used in the examination of the coals and the suitability of the coals for coke manufacture. In Section II. detailed analyses are tabulated for 367 samples, and in Section III. the same samples are described, being arranged geographically in groups.